REPORT

OF THE

SIXTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT BRISTOL IN AUGUST 1836.

VOL. V.

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1837.

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OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other Institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind, which impede its progress.

RULES.

MEMBERS.

All Persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Members of the Association, subject to the approval of a General Meeting.

SUBSCRIPTIONS.

The amount of the Annual Subscription shall be One Pound, to be paid in advance upon admission; and the amount of the composition in lieu thereof, Five Pounds.

Subscriptions shall be received by the Treasurer or Secretaries.

If the annual subscription of any Member shall have been in arrear for two years, and shall not be paid on proper notice, he shall cease to be a member; but it shall be in the power of the Committee or Council to reinstate him, on payment of arrears.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the time of the Meeting, or longer, to transact the business of the Association. It shall consist of all Members present, who have communicated any scientific Paper to a Philosophical Society, which Paper has been printed in its Transactions, or with its concurrence.

Members of Philosophical Institutions, being Members of this Association, who may be sent as Deputies to any Meeting of the Association, shall be Members of the Committee for that Meeting, the number being limited to two from each Institution.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of science.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, two or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings the affairs of the Association shall be managed by a Council, appointed by the General Committee. The Council may also assemble for the dispatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

OFFICERS AND COUNCIL, 1836–7.

Trustees (permanent).—Charles Babbage, Esq. R. I. Murchison, Esq. John Taylor, Esq.

President.—The Most Noble the Marquis of Lansdowne.

Vice-Presidents.—The Most Noble the Marquis of Northampton. Rev. William D. Conybeare. J. C. Prichard, M.D.

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Vice-Presidents elect.—The Right Rev. The Bishop of Norwich. Rev. William Whewell. John Dalton, LL.D. Sir Philip Egerton, Bart.

General Secretaries.—Rev. W. V. Harcourt. R. I. Murchison, Esq.

Assistant General Secretary.—John Phillips, Esq., York.

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Treasurer.—John Taylor, Esq., 14, Chatham Place, Blackfriars.

Treasurer to the Liverpool Meeting.—Samuel Turner, Esq.

Council.—Professor Christie, Woolwich. Professor Daniell, London. G. B. Greenough, Esq., London. H. Hallam, Esq., London. R. Hutton, Esq., London. Professor Sir W. Hamilton, Dublin. T. Hodgkin, M.D., London. J. W. Lubbock, Esq., London. Professor Lindley, London. Professor Owen, London. Professor Powell, Oxford. Dr. Roget, London. J. Robison, Esq., Edinburgh. N. A. Vigors, Esq., London. William Yarrell, Esq., London.

Secretary to the Council.—Rev. James Yates, 49, Upper Bedford Place, London.

Local Treasurers.—Dr. Daubeny, Oxford. Professor Henslow, Cambridge. Dr. Orpen, Dublin. Charles Forbes, Esq., Edinburgh. Jonathan Gray, Esq., York. George Bengough, Esq., Bristol. Samuel Turner, Esq., Liverpool. Rev. John James Tayler, Manchester. James Russell, Esq., Birmingham. William Hutton, Esq., Newcastle-on-Tyne. Henry Woollcombe, Esq., Plymouth.

OFFICERS OF SECTIONAL COMMITTEES AT THE BRISTOL MEETING.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President.—Rev. William Whewell.
Vice-Presidents.—Sir D. Brewster. Sir W. R. Hamilton.
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SECTION B.—CHEMISTRY AND MINERALOGY.

President.—Rev. Professor Cumming.
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President.—Rev. Dr. Buckland.
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SECTION D.—ZOOLOGY AND BOTANY.

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SECTION E.—MEDICAL SCIENCE.

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Vice-Presidents.—Dr. Bright. Dr. Macartney.
Secretary.—Dr. Symonds.

SECTION F.—STATISTICS.

President.—Sir Charles Lemon, Bart.
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Secretaries.—Rev. J. E. Bromby. C. B. Fripp, Esq. James Heywood, Esq.

SECTION G.—MECHANICAL SCIENCE.

President.—Davies Gilbert, Esq.
Vice-Presidents.—M. J. Brunel, Esq. John Robison, Esq.
Secretaries.—G. T. Clark, Esq. T. G. Bunt, Esq. William West, Esq.

CORRESPONDING MEMBERS.

Professor Agassiz, Neufchatel. M. Arago, Secretary of the Institute, Paris. Professor Berzelius, Stockholm. Mr. Bowditch, Boston, North America. Professor De la Rive, Geneva. Baron Alexander von Humboldt, Berlin. Professor Moll, Utrecht. Professor Œrsted, Copenhagen. Jean Plana, Astronomer Royal, Turin. M. Quetelet, Brussels. Professor Schumacher, Altona.

TREASURER'S ACCOUNT from 30th June, 1835 to 15th July, 1836.

RECEIPTS.

				£.	s.	d.
Balance in hand from last year's Account				509	16	3
Compositions from 205 Members				995	0	0
Subscriptions 1835, 1158 do.				1158	1	0
Ditto 1836, 12 do.				12	0	0
Arrears 1834, 8 do.				8	0	0
Dividend on £2500 in 3 per cent. consols, 12 months to January last	£75	0	0			
Ditto on £3500, 6 months to July	52	10	0			
				127	10	0
Received on account of Sale of Reports, 1st vol., 2nd edit.				72	2	7
Ditto ditto 2nd vol.				78	4	0
Ditto ditto 3rd vol.				215	0	0
Ditto ditto Lithographs				9	5	3
Ditto ditto Notices of Communications				0	16	3
				£3185	15	4

FRANCIS BAILY,
R. HUTTON,
J. W. LUBBOCK. } *Auditors.*

PAYMENTS.

				£	s.	d.
Expenses of Meeting at Dublin				235	8	4
Disbursements by Local Treasurers				61	15	10
Purchase of £1000 in 3 per cent. Consols				916	5	0
Salaries to Assistant Secretary and Accountant, 12 months to Christmas last				230	0	0
Paid the "Committee for the Discussion of Tide Observations"				163	0	0
Paid the Committee on British and Foreign Ichthyology				105	0	0
Ditto on Lunar Nutation				60	0	0
Paid Wm. Snow Harris for Thermometrical Experiments				50	0	0
Paid Executors of George Harvey ditto				5	0	0
Paid Professor Johnston, Printing Chemical Constants				10	0	0
Paid Rev. W. Vernon Harcourt, Experiments on Long-continued Heat				17	1	0
Paid Rev. Baden Powell, Experiments on Refraction				15	0	0
Paid Committee on Subterranean Temperature, Thermometers				15	6	0
Paid Mr. H. Carlisle, Experiments on the Heart, 1834				7	16	2
Paid Dr. Nolan ditto 1835				25	0	0
Paid Professor Phillips, Rain Gauges				9	13	0
Paid Richard Taylor, Printing Reports, 3rd vol., 1500 Copies				517	16	8
Ditto, Sundry Printing				25	3	6
Paid J. W. Lowry, Engraving for Reports, 3rd vol.				18	1	0
Paid Sundry Expenses on Publishing ditto				47	7	0
Ditto on Reports, 2nd vol.				43	8	7
July 15, Balance in the Banker's hands	540	5	6			
Ditto Treasurer's	57	9	9			
Ditto Local Treasurer's	9	18	0			
				607	13	3
				£3185	15	4

[Signed,] JOHN TAYLOR, *Treasurer.*

The following Reports on the progress and desiderata of different branches of science have been drawn up at the request of the Association, and printed in its Transactions.

On the progress of Astronomy during the present century, by G. B. Airy, M.A., Astronomer Royal.

On the state of our knowledge respecting Tides, by J. W. Lubbock, M.A., Vice-President of the Royal Society.

On the recent progress and present state of Meteorology, by James D. Forbes, F.R.S., Professor of Natural Philosophy, Edinburgh.

On the present state of our knowledge of the Science of Radiant Heat, by the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry, Oxford.

On Thermo-electricity, by the Rev. James Cumming, M.A., F.R.S., Professor of Chemistry, Cambridge.

On the recent progress of Optics, by Sir David Brewster, K.C.G., LL.D., F.R.S., &c.

On the recent progress and present state of Mineralogy, by the Rev. William Whewell, M.A., F.R.S.

On the progress, actual state, and ulterior prospects of Geology, by the Rev. William Conybeare, M.A., F.R.S., V.P.G.S., &c.

On the recent progress and present state of Chemical Science, by James F. W. Johnston, A.M., Professor of Chemistry, Durham.

On the application of Philological and Physical researches to the History of the Human Species, by J. C. Prichard, M.D., F.R.S., &c.

On the advances which have recently been made in certain branches of Analysis, by the Rev. G. Peacock, M.A., F.R.S., &c.

On the present state of the Analytical Theory of Hydrostatics and Hydrodynamics, by the Rev. John Challis, M.A., F.R.S., &c.

On the state of our knowledge of Hydraulics, considered as a branch of Engineering, by George Rennie, F.R.S., &c. (Parts I. and II.)

On the state of our knowledge respecting the Magnetism of the Earth, by S. H. Christie, M.A., F.R.S., Professor of Mathematics, Woolwich.

On the state of our knowledge of the Strength of Materials, by Peter Barlow, F.R.S.

On the state of our knowledge respecting Mineral Veins, by John Taylor, F.R.S., Treasurer G.S., &c.

On the state of the Physiology of the Nervous System, by William Charles Henry, M.D.

On the recent progress of Physiological Botany, by John Lindley, F.R.S., Professor of Botany in the University of London.

On the Geology of North America, by H. D. Rogers, F.G.S.

On the philosophy of Contagion, by Wm. Henry, M.D.,F.R.S.

On the state of Physiological Knowledge, by the Rev. William Clark, M.D., F.G.S., Professor of Anatomy, Cambridge.

On the state and progress of Zoology, by the Rev. Leonard Jenyns, M.A., F.L.S., &c.

On the theories of Capillary Attraction, and of the Propagation of Sound as affected by the development of Heat, by the Rev. John Challis, M.A., F.R.S., &c.

On the state of the science of Physical Optics, by the Rev. H. Lloyd, M.A., Professor of Natural Philosophy, Dublin.

On the state of our knowledge respecting the application of Mathematical and Dynamical principles to Magnetism, Electricity, Heat, &c., by the Rev. Wm. Whewell, M.A., F.R.S.

On Hansteen's researches in Magnetism, by Captain Sabine, F.R.S.

On the state of Mathematical and Physical Science in Belgium, by M. Quetelet, Director of the Observatory, Brussels.

On the present state of our knowledge with respect to Mineral and Thermal Waters, by Charles Daubeny, M.D., F.R.S., M.R.I.A., &c., Professor of Chemistry and of Botany, Oxford.

Observations on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland, by Major Edward Sabine, R.A., F.R.S., &c.

Report on North American Zoology, by John Richardson, M.D., F.R.S., &c.

Supplementary report on the Mathematical Theory of Fluids, by the Rev. J. Challis, Plumian Professor of Astronomy in the University of Cambridge.

Comparative view of the more remarkable Plants which characterize the Neighbourhood of Dublin, the Neighbourhood of Edinburgh, and the South-west of Scotland, &c.; drawn up for the British Association, by J. T. Mackay, M.R.I.A., A.L.S., &c., assisted by Robert Graham, Esq., M.D., Professor of Botany in the University of Edinburgh.

The following Reports of Researches undertaken at the request of the Association have been published, viz.

Report on the comparative measurement of the Aberdeen Standard Scale, by Francis Baily, Treasurer R.S., &c.

On Impact upon Beams, by Eaton Hodgkinson.

Observations on the Direction and Intensity of the Terrestrial Magnetic Force in Ireland, by the Rev. H. Lloyd, Capt. Sabine, and Capt. J. C. Ross.

On the Phænomena usually referred to the Radiation of Heat, by H. Hudson, M.D.

Experiments on Rain at different elevations, by Wm. Gray, jun. and Professor Phillips.

Hourly observations of the Thermometer at Plymouth, by W. S. Harris.

On the Infra-orbital Cavities in Deers and Antelopes, by A. Jacob, M.D.

On the Effects of Acrid Poisons, by T. Hodgkin, M.D.

On the Motions and Sounds of the Heart, by the Dublin Sub-Committee.

On the Registration of Deaths, by the Edinburgh Sub-Committee.

Report of the London Sub-Committee of the Medical Section, of the British Association on the Motions and Sounds of the Heart.

Second Report of the Dublin Sub-Committee on the Motions and Sounds of the Heart. (See vol. iv. p. 243.)

Report of the Dublin Committee on the Pathology of the Brain and Nervous System.

Account of the recent Discussions of Observations of the Tides which have been obtained by means of the grant of Money which was placed at the disposal of the Author for that purpose at the last Meeting of the Association, by J. W. Lubbock, Esq.

Observations for determining the refractive Indices for the Standard Rays of the Solar Spectrum in various media, by the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.

Provisional Report on the Communication between the Arteries and Absorbents on the part of the London Committee, by Dr. Hodgkin.

Report of Experiments on Subterranean Temperature, under the direction of a Committee, consisting of Professor Forbes, Mr. W. S. Harris, Professor Powell, Lieut. Colonel Sykes, and Professor Phillips, (Reporter.)

Inquiry into the Validity of a Method recently proposed by George B. Jerrard, Esq., for Transforming and Resolving Equations of Elevated Degrees: undertaken at the request of the Association by Professor Sir W. R. Hamilton.

The following Reports and Continuations of Reports have been undertaken to be drawn up at the request of the Association.

On the progress of Electro-chemistry and Electro-magnetism, so far as regards the experimental part of the subject, by P. M. Roget, M.D., Sec. R.S.

On the Connection of Electricity and Magnetism, by S. H. Christie, F.R.S., &c.

On the state of knowledge on the Phænomena of Sound, by the Rev. Robert Willis, M.A., F.R.S.

On the state of our knowledge respecting the relative level of Land and Sea, and the waste and extension of the land on the east coast of England, by R. Stevenson, Engineer to the Northern Lighthouses, Edinburgh.

On the Botany of North America, by Jacob Greene, M.D., and Sir W. J. Hooker, M.D., Professor of Botany, Glasgow.

On the Geographical Distribution of Insects, and particularly the order Coleoptera, by J. Wilson, F.R.S.E.

On the influence of Climate upon Vegetation, by the Rev. J. S. Henslow, M.A., F.L.S., Professor of Botany, Cambridge.

On circumstances in Vegetation influencing the Medicinal Virtues of Plants, by R. Christison, M.D., &c.

On Salts, by Professor Graham.

On the progress of Medical Science in Germany, by Dr. Graves.

On the Differential and Integral Calculus, by the Rev. G. Peacock, M.A., F.R.S.

On the present state of our knowledge of the Phænomena of Terrestrial Magnetism, by Captain Sabine, F.R.S.

On the Geology of North America, by H. D. Rogers, F.G.S., Professor of Geology, Philadelphia.

On the Mineral Riches of Great Britain, by John Taylor, F.R.S. G.S.

On the Methods of Printing for the Blind, by the Rev. Wm. Taylor, F.R.S.

On the Statistics of Dukhun, by Lieut.-Colonel Sykes, F.R.S.

On the Physical and Chemical Properties of Dimorphous Bodies, by J. F. W. Johnston, F.R.S.

Researches recommended, and Desiderata noticed by the Committees of Science at the Bristol Meeting.*

ASTRONOMY.

Mr. Lubbock's proposition for the construction of new empirical lunar Tables was referred to a Committee, consisting of Mr. Lubbock, the Astronomer Royal, Mr. Baily, Professor Rigaud, Professor Challis, and Professor Sir W. R. Hamilton; and Mr. Lubbock was requested to report to the next Meeting on the best mode of carrying it into effect.

WAVES.

An experimental investigation on Waves, having particular reference to the manner in which they are produced, the effect of wind, and the effect of the form of the canal, was entrusted to Mr. J. S. Russell and Mr. J. Robison, and a sum not exceeding 100*l.* was placed at their disposal for the purpose †.

METEOROLOGY.

The Meteorological Committee was requested to endeavour to establish hourly observations of the Barometer and Wet-bulb Hygrometer ‡, and a grant of 30*l.* was placed at their disposal for this object.

OPTICS.

The sum of 150*l.* was placed at the disposal of a Committee, consisting of the Rev. W. V. Harcourt, Dr. Turner, and Dr. Faraday, for the purpose of experimental investigations into the fabrication of glass §.

CHEMISTRY.

A series of Experiments on the comparative analysis of Iron

* In addition to those contained in vol. v.
† This inquiry is in progress.
‡ Mr. W. Snow Harris has commenced these researches at Plymouth.
§ Mr. Harcourt has been sometime occupied in this investigation.

in the different stages of its manufacture, with the hot and cold blast, was entrusted to Dr. Dalton, Dr. Henry, and Mr. H. H. Watson.

Dr. Turner was requested to undertake experiments on the Amount of Heat evolved in Combustion and other kinds of Chemical Action.

Dr. Daubeny suggested the following points with reference to Mineral Waters, as peculiarly worthy of investigation by British Chemists.

1. The chemical composition and physical properties of the water drunk in places subject to peculiar endemics, as Goitre.

2. The nature of the organic matter present in hot springs.

3. The evolution of Nitrogen from springs of ordinary temperature, as well as from thermal ones.

4. The state in which Alkali exists in certain thermal waters.

5. The means by which Silica is held in chemical solution.

6. The geological relations of the country in which thermal waters are found.

7. An exact estimate of their temperature, taken with accurate instruments at different periods of the year, together with the amount of water discharged in a given time.

8. Is Carbonate of Potash, in reality, a *very rare* constituent of thermal waters, or may not the Carbonate of Soda have been often mistaken for it?

Dr. Dalton and Mr. Wm. West were requested to investigate the presence and proportion of substances present in minute proportions in atmospheric air, according to a plan proposed by the latter.

GEOLOGY.

The Committee for procuring data on the question of the permanence of the relative level of Land and Sea on the coasts of Great Britain and Ireland, received a grant of 500*l.* in order that the subject might be satisfactorily investigated, by ascertaining with great accuracy the differences of level of a number of points in two straight lines at right angles to one another, and terminating on the sea-coast*.

The attention of observers was directed to the discovery of Plants of any kind in strata older than the coal formation.

The observation of divisional planes in Stratified Rocks, (cleavage, joints, fissures, &c.) in relation to the surfaces of

* These measures are in course of execution.

stratification, the chemical quality, and molecular aggregation of the rocks, and other circumstances, was recommended for the purpose of procuring accurate data on this part of physical Geology.

The Officers of the Ordnance Survey in Ireland were requested to make such excavations in the Peat Mosses of Ireland, as may tend to ascertain the relative periods at which they were deposited; and the sum of 50*l.* was placed at the disposal of Colonel Colby for this object.

NATURAL HISTORY.

Mr. R. Ball and Mr. Thompson, of Belfast, were requested to prepare an exact catalogue of the Animals inhabiting Ireland.

A Committee was named, consisting of Professor Henslow, Dr. Daubeny, Mr. James Yates, Dr. Henry, and Dr. Dalton, to institute Experiments on the growth of Plants under Glass, and excluded from the external Air, on the plan of Mr. N. G. Ward (described in the *Transactions of the Society of Arts*), and the sum of 25*l.* was placed at their disposal for the purpose.

Mr. R. Ball was requested to investigate the mode by which Mollusca, Annelida, and other marine Invertebrata excavate rocks.

Dr. Richardson mentioned the following desiderata in North American Zoology:

1. Fauna of Mexico, California, New Caledonia and Russian America.
2. Local Lists of the Animals of the Atlantic States of America, such as the one prepared by order of the Government of Massachusetts for that State.
3. Accurate Comparisons of the Skeletons and of Living Specimens of European and American Species supposed to be common to the two countries.
4. Monographs of the various Families of North American Mammalia, including notices of the habits of the Species, from personal observation only; and particularly of the Bats, Seals, Deer, and Pouched Rats.
5. Comparison of the Northern and Woodland Rein Deer.
6. An account of the Reptiles and Amphibia of Canada and the more northern parts of the Continent.
7. Notices of the North American Mollusca.
8. Determination of a Species of Fish which makes a loud drumming noise on the bottoms of vessels anchoring on the Coasts of Georgia and Florida, and the investigation of the causes and manner of its drumming.

The Committee of Natural History likewise requested attention to the Chemistry of Entomology, and to the Geographical distribution of Insects, more particularly with respect to the influences exercised by geological conditions and by vegetation.

MEDICAL SCIENCE.

The Chemical Composition of Secreting Organs, and their products, was referred for investigation to a Committee in London, consisting of Dr. Roget, Dr. Turner, Dr. Hodgkin, and G. O. Rees, Esq., with a grant of 25*l.*

The Physiological Influence of Cold upon Man and Animals was recommended to the attention of Mr. King, in the event of his visiting the Arctic Regions, and 25*l.* was placed at his disposal for the purpose.

An experimental Investigation of the Physiology of the Spinal Nerves was referred to Mr. S. D. Broughton, Dr. Sharpey, and Mr. E. Cock.

The Committee appointed in Dublin (vol. iv. p. 32) to report on the Pathology of the Brain and Nervous System was requested to extend its researches to the Physiology of these parts.

STATISTICS.

In furtherance of inquiries into the actual state of schools in England, considered merely as to numerical analyses, 150*l.* was placed at the disposal of a Committee, consisting of Colonel Sykes, Mr. Hallam, and Mr. Porter.

Committees were named (with power to add to their number) to draw up Instructions for observing in different branches of Science, viz.

Physical Science.—Rev. W. Whewell, Professor Forbes, Mr. Baily, Mr. Babbage, Professor Christie.

Geology.—Mr. Murchison, Mr. Lonsdale, Mr. Hopkins, Mr. Greenough.

Natural History.—Dr. Richardson, Professor Royle.

SYNOPSIS OF SUMS APPROPRIATED TO SCIENTIFIC OBJECTS

BY THE GENERAL COMMITTEE AT THE BRISTOL MEETING.

Reduction of Observations on Stars (vol. iv. p. xv.)	£500	0
Discussion of Tides (vol. iv. p. xvii.)	250	0
Ditto in the Port of Bristol	150	0
Constant of Lunar Nutation (vol. iv. p. xvi.)	70	0
Meteorological Instruments and Subterranean Temperature (vol. iv. p. xix.)	100	0
Comparative Level of Land and Sea (vol. iv. p. xxvi.)	500	0
Lens of Rock Salt (vol. iv. p. xxii.)	80	0
Hourly Observations of Barometer and Wet-bulb Hygrometer	30	0
Investigations on the Form of Waves	100	0
Experiments on Vitrification	150	0
Specific Gravity of Gases (vol. iv. p. xxiii.)	50	0
Heat developed in Combustion, &c.	30	0
Composition of Atmospheric Air	15	0
Chemical Constants (vol. iv. p. xxiv.)	24	13
Strength of Iron (vol. iv. p. xxxii.)	60	0
Mud in Rivers (vol. iv. p. xxvii.)	20	0
Subterranean Temperature and Electricity	30	0
Origin of Peat Mosses	50	0
Growth of Plants under Glass and excluded from Air	25	0
Absorbents and Veins (vol. iv. p. xxxi.)	50	0
Sounds of the Heart (vol. iv. p. xxxi.)	50	0
Chemical Composition of Secreting Organs	25	0
Influence of Cold on Man and Animals	25	0
Effect of Poisons on the Animal Œconomy (vol. iv. p. xxxi.)	25	0
Pathology of Brain and Nervous System (vol. iv. p. xxxii.)	25	0
Physiology of Spinal Nerves	25	0
State of Schools in England	150	0
Duty of Steam Engines	50	0

ADDRESS

BY

PROFESSOR DAUBENY.

GENTLEMEN,—The practice of the three preceding Anniversaries has prepared you to expect, at the first General Meeting that may be held, a short address, explanatory of the nature of those scientific objects which had chiefly occupied the Association on the former occasion, and, in particular, of the contents of the last published Volume of Transactions, in which the results of your labours are recorded. This it has hitherto been usual for the Local Secretaries of the year to prepare; and it seemed but a fair division of labour that such a task should, in the present instance, be allotted to the one, on whom, from unavoidable circumstances, the smaller share in the other duties of the office had devolved. It was this consideration, indeed, which reconciled me to the undertaking; for had I not felt that the framing of this Address was the only part of the functions of Secretary that could be discharged at a distance from the intended place of meeting, and that the time of my colleague would be engrossed by the preparatory arrangements, in which, from my absence, I was unable till lately to participate, I should have shrunk from the responsibility of a task which involved the consideration of questions of a high and abstruse character, to several of which I feel myself but ill-qualified to do justice. It is nevertheless, be assured, with extreme diffidence that I enter upon a task which has, at former meetings, been executed by men so eminent in science, and that I presume, though one of the humblest members of this great body, to exhibit to you a brief sketch of the labours of some of those individuals, whose presence amongst us sheds a lustre over our proceedings, and has contributed, more than any other motive, to draw together this great concourse here assembled.

There is one consideration, however, that may perhaps give me some claim to your indulgence: I mean that of my having attended to all the meetings of this Association up to the present time, and hence having traced its progress through all its various stages, from its first small beginnings at York, up to this period of its full maturity; thus having

been enabled, by an actual participation in the business of the meetings, to form a juster estimate of the real condition of the Association, and of the services it has rendered to science, than the public at large could collect.

Thus circumstanced, for example, I have become sensible of results, flowing from the meetings of this great body, which can scarcely figure in a Report, or find expression in the accounts transmitted by the periodical press:—I have been struck by the enthusiasm elicited by the concourse of congenial minds—the friendships formed and cemented—the trains of experiment first suggested, or prosecuted anew after being long abandoned;—above all, the awakening of the public mind to the just claims of Science by the celebration of these Anniversaries.

But, important as these consequences may appear, and imperfectly as they may be understood by persons who keep aloof from our meetings, it seems almost superfluous to dilate on such topics to those actually present at them, when the mere fact of their being congregated here in such numbers, conveys the best assurance that such is already their conviction. Nor is it merely the assembling of so large a portion of the respectable inhabitants of this city and neighbourhood, nor yet the attracting from a distance so great a number of the mere amateurs of science, which justifies me in this conclusion; but it is the presence of so many hard-working, so many successful, cultivators of physical research, and their devoting to the service of the Association that most valuable of their possessions, their time, which gives me a right to assume, that the minds of those qualified to judge on such matters (and those only can be fully qualified who have been present) are already made up respecting the beneficial influence which this Association is exerting.

The volume, indeed, which now lies upon the table, and which contains the results of our last year's proceedings, not only amply sustains the former character of these Transactions, but even shows more strongly than those which have preceded it, the power which the Association has been exercising in the direct advancement of Science. It contains, in the first place, several valuable contributions to our knowledge of Magnetism,—a branch of science, which within a few years, stood in a manner isolated from the rest, but which now, thanks to the researches of living philosophers, is shown to be intimately connected with, or rather to be one of the manifestations of that mysterious, but all-pervading power, which seems to be displayed not less in those molecular attractions that bind together the elements of every compound body, than in the direction imparted to the loadstone; perhaps even in the light and

heat which attend upon combustion, no less than in the awful phenomena of a thunder-storm.

Considering the connexion that subsists between the sciences of Heat, Electricity, and Magnetism, and considering, likewise, the efforts made with various degrees of success, and by men of very unequal pretensions, to develop the laws of each of these sciences in accordance with mathematical formulæ, one cannot wonder that the Association should have been anxious to assign to a member, no less distinguished for the depth of his mathematical attainments than for the range of his acquaintance with modern science, the task of drawing up a Report on the theories of these three departments of Physics, considered in relation one to the other. This accordingly has been executed by Mr. Whewell, whose Report stands at the commencement of the volume.

The point of view in which he was directed to contemplate the subject possesses an interest to all who are engaged in the investigation of natural phenomena, whatever may have been the particular bent to which their researches have been directed.

All the physical sciences aspire to become in time mathematical: the summit of their ambition, and the ultimate aim of the efforts of their votaries, is to obtain their recognition as the worthy sisters of the noblest of these sciences—Physical Astronomy. But their reception into this privileged and exalted order is not a point to be lightly conceded; nor are the speculations of modern times to be admitted into this august circle, merely because their admirers have chosen to cast over them a garb, oftentimes ill-fitting and inappropriate, of mathematical symbols. To weigh the credentials of the three physical sciences which have been pointed out as mathematical, was therefore a proper office for the Association to impose upon one of its members; and I believe it will be found that no small light has been thrown upon the subject by the manner in which that trust has been discharged.

With regard, however, to Magnetism, which forms one of the subjects of Mr. Whewell's Report, much still remains to be done, before the mathematician can flatter himself that a secure foundation for his calculations has been established; and the materials for this foundation must be collected from such a variety of isolated points, distant one from the other, both in time and place, dependent for their accuracy upon the occurrence of favourable circumstances, and, after all, demanding from the observer an uncommon union of skill and experience, that there is perhaps no scientific undertaking for which the co-operation of public bodies, and even of governments, is more imperiously demanded; and the Association has, in consequence, both engaged its members in

the prosecution of these researches, and has proposed to obtain for them the national assistance. To call the attention therefore of the scientific world, in a greater degree, to the present condition of our knowledge as to Terrestrial Magnetism, was the object of Captain Sabine's Report in the present volume of these Transactions; and this he has accomplished by presenting us with an elaborate abstract of the work which Professor Hansteen, of Copenhagen, had published upon that subject.

This mathematician, in the year 1811, constructed a chart, in which were laid down, so far as could be ascertained, the lines of equal variation and dip of the magnetic needle in all parts of the world. It is curious to observe the degree of coincidence which exists between these lines representing the distribution of the magnetic force, and the isothermal lines by which Humboldt has expressed the distribution of heat over the earth's surface; and this apparent connexion, the cause of which remains a mystery, is calculated to stimulate our zeal for investigating the phenomena of both. Nor is it less interesting to trace in what degree these later observations appear to confirm the general conclusions arrived at by the celebrated Halley more than a century before. That astronomer had inferred, from a general review of all that was then known with regard to the variation and dip of the needle, that there must be two magnetic axes; whilst the gradual shifting of the line of no variation from west to east, led him to propose the ingenious, though whimsical hypothesis, of a moveable globe existing in the interior of the earth we inhabit, actuated by the same forces as those which propel the hollow sphere surrounding it, and, like it, possessing a north and south magnetic pole. This interior globe, if it be supposed to move with somewhat less rapidity than the exterior shell, might, as he conceived, produce a gradual shifting of the poles from east to west, and thus account for the difference observed from time to time in the position of the magnetic axes.

Now the researches of Professor Hansteen confirm the existence of two magnetic axes, though they led him to discard the hypothesis by which Halley accounted for the progressive shifting, which, indeed, the recently-discovered connexion between Electricity and Magnetism gives us hopes of explaining more satisfactorily, as has been shown by Professor Christie in the Report read by him at our third meeting.

Since the publication, however, of the great work to which his Magnetic Chart is appended, Professor Hansteen, aware of the mystery which still overhangs the subject, has been zealously employed in attempting to remove it, by ascertaining the present state and progressive change of the magnetic forces. He has accordingly employed himself

in making observations on the line of no variation, or, as he prefers to call it, the line of convergence which passes through Siberia; and, by a fortunate concurrence of circumstances, the north-western expedition lately undertaken by British navigators, has afforded the means of obtaining, at the very same time, corresponding ones on the similar line, which extends from Hudson's Bay through the United States of America. Thus the position of these lines in the above two most interesting localities, has been almost simultaneously determined with an exactness before unequalled.

In conjunction with Captain Sabine, Professor Lloyd, of Dublin, has contributed, in another way, at the instance of the Association, to extend our acquaintance with the empirical laws of this interesting department of science. This they have effected by determining the dip and variation of the magnetic needle in different parts of Ireland, which it was considered the more important to ascertain, from the situation of that island in the most westerly point of Europe, at which observations could be instituted.

The distribution of the earth's magnetism through this country was determined by the above-named observers; first by a separate series of observations relating to the force of that portion of the magnetic influence which operates horizontally; secondly, by a similar series on the dip of the needle; thirdly, by means of observations both on the dip and intensity of the magnetic force made at the same time and with the same instruments.

It would occupy too much of the time of the Association, were I to attempt to point out, however briefly, the precautions adopted, and the corrections applied, in order to arrive at accurate results. I shall therefore only remark, that the method by which the intensity of the magnetic force was ascertained, resembles in principle that by which philosophers determine the force of gravity. For as a pendulum when set in motion oscillates on either side of the vertical line by the force of gravity, so the needle, when drawn out of its natural position, will oscillate on either side of the magnetic meridian by the earth's magnetic force, and hence, in either case, the force may be inferred to vary, inversely, as the square of the time in which a certain number of vibrations are performed. In order, however, to arrive at trustworthy results, many precautions must be adopted, which are pointed out in detail in Professor Lloyd's memoir, and in particular one relating to temperature; it being found that the same needle will vary in force about 1-4000th part for every degree of Fahrenheit. Having, however, arrived at a determination of the intensity of the magnetic force at the two extremities of the Island

by a sufficiently extended series of observations, namely, at Limerick by Captain Sabine, and at Dublin by Professor Lloyd, and having compared the results with those obtained by means of the same needles at a spot out of Ireland, whose magnetic intensity had been previously settled, by availing themselves of the observations of Captain James Ross, at London, our authors proceeded to estimate the relative intensity of the magnetic force at twenty-five different places within the compass of Ireland, by observations made at each of these simultaneously with others at Dublin or at Limerick. They thus obtained data by which to exhibit the law of Terrestrial Magnetism in Ireland, in a similar manner to that by which Humboldt laid down the laws of the distribution of Terrestrial Heat. The same principle was adopted in determining the lines of dip as of intensity, and the general result was obtained, that the angle which the lines of dip in Ireland make with the meridian of Dublin is 56° 48′, and that the dip increases one degree for every distance of 101 miles in a direction perpendicular to these lines.

The preceding method of estimating the intensity by the number of vibrations in a given time only applies to that portion of the earth's magnetic force which operates in a horizontal direction. In order, therefore, to determine the whole amount of this force, observations of the kind above alluded to must be combined with others on the dip. This third series accordingly was instituted at twenty-three different stations in Ireland, and the result arrived at was, that the lines of absolute intensity make an angle of 33° 40′ with the meridian of Dublin, and that the intensity increases in a direction perpendicular to these lines by the 1-100th part for every 95 miles of distance.

The importance of these researches in extending our knowledge of Terrestrial Magnetism, and affording the data on which a correct theory with respect to this subject may hereafter be based, will be felt even by those who do not fully appreciate the skill and labour they required; and no better proof could be afforded of the substantial benefits arising from such an institution as the British Association, than that of having originated such an inquiry.

On the subject of Heat, Dr. Hudson, of Dublin, has detailed some experiments, the tenor of which he considers incompatible with the commonly received theory respecting its radiation, which we owe to Professor Prevost, of Geneva, inasmuch as their tendency would be to establish that cold is equally radiated with heat—a result inconsistent with the notion of the former being a negative quality. Without professing himself a convert to the views of Professor Leslie, who supposed heat to be radiated in consequence of the alternate expansion and con-

traction of the air around, producing a series of aerial pulses, Dr. Hudson considers that their particular experiments appear more reconcileable to his than to Prevost's theory, and, therefore, that the former deserves to be further investigated.

In compliance with a wish expressed by the Meteorological Committee, Dr. Apjohn has investigated the theory of the Wet-bulb Hygrometer, and communicated an account of his experiments on this subject at the Dublin Meeting. His paper, having been already published in the Transactions of the Dublin Academy, does not appear in our Report, which, however, contains two very interesting communications on subjects of Meteorology.

Mr. Snow Harris has presented a statement of the variations of the thermometer at the Plymouth Dock-yard, as noted down by the wardens and officers of the watch, during every hour of the day and night, commencing on the 1st of May, 1832, and terminating in December, 1834, which are also checked by a concurrent series of thermometrical observations, registered every two hours, at the request of the Association, by the late lamented Mr. Harvey.

Thus have been afforded us, for two complete years, observations to contrast with those taken during 1834 and 1835, at Leith Fort, under the superintendence of the Royal Society of Edinburgh.

Mr. Snow Harris has deduced from an average of these observations the following important results :—

1st, The mean temperature of various seasons, as well as that of the entire year.

2ndly, The daily progression of temperature.

3rdly, The two periods of each day at which the mean temperature occurs.

4thly, The relation between the mean temperature of the whole twenty-four hours, and that of any single hour.

5thly, The average daily range for each month.

6thly, The form of the curves described by the march of the temperature between given periods of the day and night.

In this manner has been accomplished one of the first undertakings suggested by the British Association to its members, and promoted by its funds, and the true form of the diurnal and annual curves in an important station of our southern coast been attained, as a standard of comparison with that arrived at by Sir David Brewster in the latitude of Edinburgh, and from which they exhibit in the results some extremely curious and important discrepancies.

Professor Phillips and Mr. Gray have presented us with a continuation

of those curious observations on the Quantities of Rain falling at different elevations, which had formed the subject of two preceding communications published in these Transactions.

In the first series of these it had been shown by Professor Phillips that the difference between the quantities of rain that fell depended on two conditions—1st, the height, and 2ndly, the temperature; the former circumstance determining the *ratio* of the difference between the two stations, and the latter its *amount*.

In the second series he showed that the ratio likewise varied at different seasons.

The present or third series presents us with a formula for expressing these variations, and points out its correspondence with the observations made.

That the quantity of rain which falls should be greater at lower than at higher elevations, is a result which, though at first sight it may appear paradoxical, is quickly perceived to harmonize with the fact, that drops of rain descend from a colder to a warmer atmosphere, and consequently condense a portion of the aqueous vapour which exists suspended in the lower strata. But that the rate of increase should actually be found reducible so nearly to a mathematical formula, is certainly far more than could have been expected, and its successful accomplishment is calculated to give us hopes that other meteorological phenomena, which seem at present so caprioious as to baffle all calculation, may at length be found reducible to certain fixed principles. So far as relates to the rain that falls at York, the results are regarded by Professor Phillips as sufficiently complete, but he strongly urges the advantage of instituting in other spots selected in different parts of the kingdom similar observations, which, if executed simultaneously, would mutually illustrate each other, and be likely to throw much additional light on the theory of rain, and on the distribution of vapour at different heights.

An important practical paper has been published in our Transactions of this year by Mr. Eaton Hodgkinson, on the effect of impact upon beams. It is a continuation of some researches which he communicated at the preceding Meeting, on the collision of imperfectly elastic bodies. In these experiments he had laid down the general principles relating to the collision of bodies of different natures, and had obtained amongst other results the following,—namely, that all rigid bodies possess some degree of elasticity, and that amongst bodies of the same class the hardest are generally the most elastic.

It remained to be seen whether this difference in elasticity influenced

the force of their impact, and this he has shown in his present memoir not to be the case, the hardest and most elastic substances producing no more effect upon a beam than any soft inelastic body of equal weight. Various other conclusions of much practical as well as theoretical importance are stated in the above paper, and the results are severally borne out by an elaborate and careful series of experiments.

Our Foreign Associate, Mons. Quetelet, has presented to us a sketch of the progress and actual state of the Mathematical and Physical Sciences in Belgium, of interest, not only from the information it conveys, but likewise as the contribution of a distinguished foreigner, who had evinced already his respect for this Association, by attending one of its meetings. The appearance of this Report, together with that published in the preceding volume by Professor Rogers, of Philadelphia, on the Geology of North America, I regard as a new proof of our prosperity. It shows that the Association has begun to exert an influence over the progress of Science, extending even beyond the sphere which, by its name of British, it claims for its own; and that it has enlisted in its behalf the sympathies not only of our Transatlantic brethren, who speak the same language and boast of a common extraction, but likewise of those Continental nations, from whom we had so long been severed.

On the subject of Chemistry, our transactions of this year contain only a short report by Dr. Turner, explanatory of the sentiments of the members of the Committee which had been appointed the preceding year, to consider whether or not it would be possible to recommend some uniform system of Notation which, coming forward under the sanction of the most distinguished British chemists, might obtain universal recognition. In the discussion which took place when this subject was brought before us at Dublin, three systems of Notation were proposed, differing one from the other no less in principle than in the end proposed by their adoption.

The first was that suggested by the venerable founder of the Atomic Theory, Dr. Dalton, who aimed at expressing by his mode of notation, not merely the number of atoms of each ingredient which unite to form a given compound, but likewise the very mode of their union, the supposed collocation of the different particles respectively one to the other. He proposed, therefore, a sort of pictorial representation of each compound which he specified, just as in the infancy of writing each substance was indicated, not by an arbitrary character, but by a sign bearing some remote resemblance to the object itself. This, therefore, may be denominated the Hieroglyphical mode of Chemical Notation; it was of great use in the infancy of the Atomic Theory, in familiarizing

the minds of men of science to the mode in which combinations take place, and thus paved a more ready way to the reception of this important doctrine. Even now it may have its advantages in conveying to the mind of a learner a clearer notion of the number and relation of the elements of a compound body one to the other; and in those which consist only of two or three elements a symbolic representation after Dr. Dalton's plan might be nearly as concise as any other. But it would be difficult, consistently with brevity, to express in this manner any of those more complicated combinations that meet us in every stage of modern chemical inquiry, as for instance in the compounds of Cyanogen, or in the proximate principles of organic life.

The second mode of Notation is that, in which the method adopted in Algebra is applied to meet the purposes of Chemistry. This method, whilst it is recommended by its greater perspicuity, and by its being intelligible to all educated persons, has the advantage also of involving no hypothesis, and being equally available by individuals who may have taken up the most opposite views of the collocation of the several atoms, or who dismiss the question as altogether foreign to their consideration. This, therefore, may be compared to the alphabetical mode of writing in use amongst civilized nations; the characters indeed may differ, the words formed by a combination of these characters may be very various, but the principles on which they are put together to express certain sounds and ideas are in all countries the same.

The third method of Notation, which has been recommenced by the authority of several great Continental chemists, and especially of Berzelius, resembles rather a system of short-hand than one of ordinary writing; its express object being to abbreviate, so far as is consistent with perspicuity, the mode of Notation last described. But although most chemists may find it convenient to employ some of these abbreviated forms of expression, it seems doubtful whether any particular amount of them can be recommended for general adoption, since the necessity for it will vary according to the habits of the individual, the nature of his inquiries, and the objects for which his notes are designed.

A chemist, for example, the character of whose mind enables him quickly to perceive, and clearly to recollect minute distinctions, may find a much more abbreviated style of notation convenient, than would be at all advisable to others; one who is engaged in the analysis of organic compounds will be more sensible of the utility of such symbols, than another who is conversant chiefly with a less complicated class of combinations; and one who notes down the results of his experiments for the benefit of private reference, and not with any immediate view to

others, may indulge in a more concise and complex system of notation, than would be convenient, where either of the latter objects were contemplated.

As the shortest road is proverbially not always the most expeditious, so in Chemical Notation more time may often be lost in correcting our own blunders and those of the compositor, where dots and commas of many sorts are introduced in the place of initial letters to express certain elements, than was gained by the more compendious method of expression employed. Add to which, in the preference given to one set of dots over another, or in the particular collocation of them, above, below, or at the side of, the symbol to which they are referred, we have no fixed principle to guide us, and can therefore only be determined by the greater or less frequent adoption of one method than of another.

Perhaps, therefore, all that can be hoped from a Committee of British Chemists would be, to set forward the various uses of some system of Chemical Notation, the purposes for which each of those brought before them seems chiefly applicable, and the degree of prevalence which one has obtained over the rest.

If I may be allowed to offer my own humble opinion on a point which has been so much debated amongst British chemists, I should remark, that for the purpose of rendering more intelligible to beginners the mode in which various bodies are supposed to combine, the Daltonian method of Notation may still be of use, just as pictorial representation often comes in aid of verbal description to convey the idea of a complex object; but that where the design is to state in the clearest and least hypothetical terms, the nature of a series of combinations, a mode of notation as closely as possible approaching to that adopted in algebra seems preferable—remembering always, that as in algebra we omit certain signs for the sake of greater brevity, so it may be allowable to do in applying its principles to Chemistry; these abbreviations being of course the most advisable in cases, where, by reason of the greater number of elements involved, the expression of them at whole length would occupy so much space, as to prevent the whole from being comprehended at a glance.

The above remarks will not, I believe, be found inconsistent with the spirit of the brief report which Dr. Turner has communicated, and which is to the following effect:—

1st. That the majority of the Committee concur in approving of the employment of that system of Notation which is already in general use on the Continent, though there exist among them some difference of opinion on points of detail.

2ndly. That they think it desirable not to deviate in the manner of notation from algebraic usage, except so far as convenience requires.

And 3dly. That it would save much confusion if every chemist would state explicitly the exact quantities which he intends to represent by his symbols.

But I must hasten on to those few other Reports which the present volume contains, but on which I shall have the less to say, as they relate to subjects connected with Anatomy and Physiology, of less general interest to a mixed audience.

Dr. Jacob has replied to a query proposed by the Zoological Committee at a former meeting with respect to the uses of the infra-orbital cavities in Deers and Antelopes, and has pronounced them to be designed as the receptacles of a peculiar odoriferous secretion.

Dr. Hodgkin and Dr. Roupell have detailed a series of experiments and observations relative to the specific mode of action of acrid poisons, which, whether at once introduced into the stomach, or the circulation, by injection into the veins, seem to operate primarily in the same manner, as irritants to the mucous membrane.

The Dublin Sub-Committee appointed for the purpose, have given in a report connected with a subject of great pathological interest, respecting which none, but the experienced medical practitioner, ought to pretend to pass a decided judgment.

Nevertheless, when I look back to the early period of my own professional studies, and recollect the obscurity in which diseases of the heart appeared then to be involved, when their remedy seemed so desperate, as to suggest to one of the most distinguished writers on the subject the motto "*Hæret lateri lethalis arundo*" as appropriate to his work, and as significant of the probabilities of cure, and when their very nature was known but partially, and could only be guessed at by methods purely empirical,—when I recollect all this, I cannot refrain from congratulating those of my brethren who are engaged in the duties of the profession from which I am myself a *deserter*, on the discovery of a new instrument of investigation in diseases of this nature, the use of which, being founded on physiological principles, seems susceptible of greater improvement, and more extended application, in proportion as our knowledge of the animal œconomy advances.

But in order properly to avail ourselves of the indications of disease afforded by the differences of sound transmitted through the integuments by the heart, it is necessary that we should be acquainted with the nature of its pulsations, and of the sounds occasioned by them in a healthy state, and this information it has been the object of the Dublin

Sub-committee to embody in the report which was communicated by them last year to the Medical Section.

Such are the principal contents of the volume which records the scientific labours instituted at the express suggestion of the general body, and prepared for its last Meeting; but, exclusively of these, many very valuable and elaborate investigations were submitted to the several Sections without any such solicitation.

I may instance in particular the views with respect to the classification and the geological distribution of Fishes, expounded to us with so much ability by Mons. Agassiz, whose important labours might perhaps have been suspended, but for the timely assistance dealt out to him by this body, and the opportunities which its Meetings afforded, for giving them that publicity which they deserved.

I may point out likewise the important results submitted to the Geological Section by Mr. Murchison and Professor Sedgwick, with reference to the Silurian formations of Wales and Shropshire, and the multitude of facts illustrative of the physical structure of Ireland, which were elicited by the exhibition of Mr. Griffith's Geological Map, an undertaking which, coupled with the researches of Mr. Mackay on the plants indigenous to that country, promises to render us as well acquainted with the Natural History of this portion of the Empire, as we already are with respect to Great Britain itself.

Nor must I forget the researches on Comparative Anatomy laid before the Medical Section by Dr. Houston, who pointed out the existence of reservoirs connected with the veins leading to the lungs in the Cetacea—an admirable contrivance, by which Nature has provided for the unobstructed circulation of their blood, in spite of the enormous pressure which they have to sustain at the great depths to which they are wont to dive.

The Members of the Association had also the satisfaction of witnessing the ingenious manner in which Mr. Snow Harris contrives to render quantities of Electricity appreciable by the balance, like those of any gross material substance; whilst such as could enter upon the more refined branches of mathematical analysis must have listened with profound interest to the exposition given by Professor Hamilton, of the ingenious labours of Mr. Jerrard, of this city, in solving Equations of the higher orders.

What proportion of such inquiries may be attributable to the influence of this Association, and how much might have been merely the

result of that increased taste for physical research to which the Association itself owes its existence, I do not pretend to determine; this, however, at least must be allowed, that many of the most important truths communicated might have been long in winning their way to general recognition, and in ridding themselves of those exaggerated and mistaken views, which are the common accompaniments of every infant discovery, had it not been for the opportunities which these Meetings afford, of examinining the very authors of them, with respect to their own inquiries; of confronting them with others who have prosecuted similar trains of research; of questioning them with respect to the more doubtful and difficult points involved; and of obtaining from them, in many instances, an exhibition of the very experiments by which they had been led to their conclusions.

And it is this personal intercourse with the authors of these great revolutions in Science, which in itself constitutes one of the principal charms of these meetings. Who would not have listened with delight to a Newton, had he condescended to converse on the great truths of Astronomy; to a Jussieu, imparting to a circle of his intimates in his own garden at Trianon, those glimpses with respect to the natural relations of plants, which he found it so difficult to reduce to writing; or to a Linnæus, discussing at Oxford his then novel views with respect to the vegetable kingdom, and winning from the reluctant Dillenius a tardy acknowledgment of their merits? And in like manner, who does not value the privilege of hearing a Dalton discourse on these occasions on his own Atomic Theory, or a Faraday, (who, however, I regret to say, is on this occasion prevented by illness from attending), explain orally the steps by which he has traced the relations between Electricity and Magnetism, although every one is aware, that the principal facts, both with respect to the one and the other, have long since been made public by their respective authors, and have been abundantly commented upon by others.

And nowhere, perhaps, is it more desirable to instil those sentiments to which I have alluded, than within the precincts of those provincial cities which the Association now proposes to visit. The inhabitants of those great emporiums of Commerce and Manufactures are indeed often enough reminded, that processes directed by the guidance of Chemistry and Mechanics constitute the very basis of their prosperity, but they are too apt to regard these and other kindred sciences, as the instruments merely of material wealth, and to deem it superfluous to prosecute them further than they are seen to conduce to that one end.

That such notions are short-sighted, even with reference to the prac-

tical applications of the Arts, it would not be difficult to show; but I am ambitious to place the question on a higher ground, and the presence amongst us of such individuals as I have mentioned, will do more towards that object than volumes of argument would effect. It will convince us at least, that other roads to distinction, besides that of mere wealth, are opened to us through the instrumentality of the Sciences; for although, thanks to the spirit of the age, which in this respect at least stands advantageously distinguished from those preceding it, the discoverers of important truths are not, as heretofore, allowed to languish in absolute poverty, yet the debt which society owes to them would be but inadequately paid, were it not for the tribute of respect and admiration which is felt to be their due.

It has indeed been sometimes objected, that too large a share of public attention is in this age directed to the Physical Sciences, and that the study of the human mind, the cultivation of literature, and the progress of the Fine Arts have been arrested in consequence. In what degree the accusation is well founded, this is not the place to inquire, although, when we look round upon the many literary characters that adorn this age, we should rather suppose the remark to have arisen from the increasing interest in Science, than from any diminished taste for other studies.

If this complaint however had any foundation in truth, it would only supply a stronger argument in favour of an Association like the present, the express object of which is to correct that narrowness of mind which is the consequence of limiting ourselves to the details of a single science, or, it may be, to a single nook and corner of one, and therefore to render the prevailing taste of the times more subservient to mental culture, and therefore a better substitute for the studies it is alleged to have superseded;—an Association too, which, with no narrow and exclusive feeling towards those pursuits which it is designed to foster, extends the right hand of fellowship to men of eminence in every department upon which the human mind can be exercised, and which would have felt that no higher honour could have been bestowed upon its present Meeting, than by the attendance of the great poet, and the great sculptor, who own Bristol as their native city.

To alter indeed the character of the period in which we live, is as much beyond the efforts of individuals, as to fix the time of their birth, or the country and station in which their lot is cast; and it is perhaps inevitable, that an age and country so distinguished above all others for the advancement of arts and manufactures, should attach an increased importance to those sciences on which both the latter are dependent.

But it is at least consolatory to reflect, that Providence has attached to every one of those conditions of society through which nations are destined to pass, capabilities of moral and intellectual improvement, and that the very sciences which so amply minister to our physical enjoyments, also afford the means of those higher gratifications which spring from the exercise of the taste and imagination. Thus, although it may not be easy for the citizen to indulge to any extent in studies alien from the pursuits which engross his hours of business, yet it cannot be deemed incompatible with the latter to mount up to the principles of those sciences which are connected with the arts he practises; to study their relation one to the other; and to acquaint himself with the steps by which they have reached their present eminence. It cannot but be useful to the chemical manufacturer to study the laws of that molecular attraction which binds together the elements of the substances which he prepares; to the mechanic to examine the process of the arts in connexion with the general laws of matter; to the miner or land-surveyor, to inform himself with respect to the physical structure of the globe; to the agriculturist, to become acquainted with the principles of vegetable physiology, and the natural relations of plants.

For my own part, intimately connected as I am, both with the first of the commercial cities, and also with the first of the universities, that welcomed the British Association within its precincts, warmly interested in the prosperity of both, and officiating as Local Secretary on either occasion, I have felt personally gratified at seeing the selection of these places justified by the cordiality of our reception in both, and at witnessing the new vigour which has been infused into the Association, in consequence of the support it has therein received. But how much will that gratification be augmented if it should be found hereafter that the benefit in either case has been mutual; that these Meetings have cemented those bonds of union between the academical and the commercial portion of the British community, which it is so desirable to maintain; and that, whilst the University to which I belong has reaped advantage, by having its attention called to the interest felt in the physical sciences generally throughout the kingdom, my fellow-citizens here will in like manner catch the spirit which pervades our body, and will engage in the pursuit of knowledge, with a juster conception of its high objects, and with a zeal and devotion to its cause, which will not be less practically useful, because it is stimulated by a more disinterested love of truth; less capable of ministering to the operation of the arts, because it is also rendered subservient to mental discipline and improvement!

REPORTS

ON

THE STATE OF SCIENCE.

Report on the Present State of our Knowledge with respect to Mineral and Thermal Waters. By CHARLES DAUBENY, *M.D., F.R.S., M.R.I.A., &c., Professor of Chemistry and of Botany, Oxford.*

THE term "Mineral Water," in its most extended sense, comprises every modification existing in nature of that universally diffused fluid, whether considered with reference to its sensible properties, or its action upon life. For as every agent which affects the animal system in a peculiar manner, must be presumed to possess something in its constitution which is wanting in others, the circumstance of any remarkable medicinal virtue residing in a spring ought, if well established, to be regarded, as a proof of something distinctive in its physical or chemical nature. All medicinal springs therefore will range themselves under the head, either of thermal, or of mineral waters, deriving their properties from the temperature they possess, or from some peculiarity of saline or gaseous impregnation; but the subject-matter of the present Report embraces a much wider field than this, including the consideration of every other description of water, whether circulating through the atmosphere, collected in the ocean, or distributed over the surface of our continents. Definition.

The former of these, however, or atmospheric water, as being the purest form of any which nature presents, will supply us with the fewest materials for comment. I ought however to notice the reported detection in it of small quantities, of iron, nickel, manganese, of certain ammoniacal compounds, and of a peculiar organic substance chemically different from the extractive matter and the gluten of plants and animals, which from its yellowish brown colour has been called pyrrhine. 1st. Atmospheric Water.

According to the statement of Zimmermann*, formerly Professor of Chemistry at Giessen, all the above matters are to be found in snow-water, but pyrrhine was first detected in a red shower of rain which fell at that town in 1821. The water that contained it was of a peach red colour, and flakes of a hyacinthine tinge floated on its surface. This latter was the substance designated by the above name.

Some of these results have been since confirmed by Dr. Witting†, of Hoxter on the Weser, who declares, that he has ten times examined the rain-water from his own neighbourhood, and that whilst in seven trials he found it destitute of fixed principles, in three he detected in it foreign matter, which in one case proved to be muriate of potash, and in the other two free muriatic acid. He also found the air collected from elevated spots on the Hartz mountains to contain the same organic principle which Zimmermann had designated as pyrrhine, thus confirming the probability of its existence in rain-water.

He remarked, that the atmosphere of a place contained in general the same foreign ingredients which the first fall of rain brings to the ground, such, for example, as traces of muriates, of free muriatic and carbonic acids, and of carburetted hydrogen gas. Rain which fell during a north-west wind commonly contained much carbonic, together with traces of phosphoric, acid. The latter was discovered on several occasions in rain which had fallen during particular states of the weather; and Dr. Witting goes on to state, that certain plants exhale it, so that when they are confined under glass, traces of this acid may be detected on the internal surface of the latter.

In four out of twelve trials snow was found to exhibit signs of muriatic acid, and of an organic colouring matter. Hail and sleet collected in the spring of 1824 contained a large quantity of this latter substance, but none either of the acids nor the salts above mentioned. Dew showed vestiges of nitric and muriatic acids, but in hoar-frost no signs of any extraneous matter were discoverable.

Upon the whole then it may be observed, that of the above circumstances, the one relating to the existence of organic matter in atmospheric water is best substantiated; and this has more lately been ascribed by the distinguished Ehrenberg to the ova of a particular class of Infusoria (the Polygastrica), which, being raised by currents and by evaporation, fill the atmosphere, and thus produce the pyrrhine observed by chemists‡. The presence of salts and of acids, in the atmosphere, and consequently in water derived from it, is also supported by sufficient evidence.

* Kastner's *Archiv.*, vol. ii. † Kastner's *Archiv*, vol. v.

‡ Ehrenberg in *Jameson's Journal* for 1831, "on Blood-red Water."

Nitric acid, indeed, seems to be spontaneously generated from its elements under certain circumstances as yet but imperfectly understood, as during the decomposition of water by voltaic electricity*, and in the case of the formation of nitre on walls. We need not, therefore, be astonished to find it sometimes present in atmospheric water. Common salt is also taken up in small quantities by aqueous vapour, and the same is the case with many other alkaline and earthy compounds.

But the existence of metallic bodies in the atmosphere requires further confirmation, although I am not disposed to reject the statements of Zimmermann on this point as altogether unworthy of examination. Faraday indeed has shown†, that such matters cannot be suspended there by the mere repulsive force of heat, since every substance, according to his experiments, possesses a certain fixed point, below which no spontaneous volatilization of its particles takes place, and the limit of volatility in these metals greatly surpasses the highest temperature which the atmosphere ever attains.

Still, however, it becomes a distinct question, whether such bodies may not exist there by virtue of their affinity for others; and experiments recently made in Italy seem to show, that in some manner or other they are so suspended. Thus, Fusinieri‡ has stated, that electrical light carries with it metallic bodies in a state of incandescence, and that ordinary lightning deposits upon the substances with which it comes into contact, sulphur, and iron, in a metallic, as well as in an oxidized, condition. Hence according to him arises the smell which always accompanies thunder, and hence the pulverulent matter deposited round the fractures occasioned in those solid bodies which the lightning traverses.

The connexion of these researches with the origin of meteoric stones is too obvious to require our insisting on; and hence it becomes of the more importance that some fresh experiments and observations should be set on foot, in order that the question may be finally determined.

To conclude my account of the foreign bodies met with in meteoric water, I may mention, that the fact of carburetted hydrogen having been detected in the water of rain, snow, and hail, is the more credible, inasmuch as Boussingault§ has found this same gas in the atmosphere surrounding large cities.

With respect to sea-water, the next modification of this fluid 2ndly. Water of Seas.

* See Davy's Experiments, 1807, *Philosophical Transactions.*

† *Philosophical Transactions*, vol. cxvi. p. 2.

‡ Becquerel, *Traité d'Electricité*, vol. iii. p. 157.

§ *Annales de Chimie.*

which I shall notice, the only new mineral substances discovered in it are, potash by Dr. Wollaston, iodine by Pfaff, and bromine by Balard. The quantity of the two former is so minute, that the variation of either in different seas still remains undetermined; but the proportion of bromine is considerable enough to admit of being measured with something like precision.

I have myself found it to vary considerably in different samples which I examined.

Thus, 1 gallon of sea-water, taken off Cowes, afforded of bromine 0·915 grain; in the Bay of Naples, 0·925 grain; off the coast near Marseilles, 1·260 grain.

I have since examined two specimens of sea-water taken on the line, the former in long. 21° 30′ west, the latter in long. 84° 30′ east, and in both cases detected a larger proportion of bromine than in any of those above mentioned. In one sample, indeed, the quantity indicated was so large, that I suspect some error to have crept into the analysis, and therefore forbear quoting it; in the other, which probably was correct, it amounted to no less than 1·7 grain to the gallon.

I mention these facts merely to stimulate inquiry, deeming them too few to allow of my grounding any inference at present upon them. It may be right however to state, that the quantity of bromine did not depend upon the greater amount of saline matter in some of the specimens than in others, this being found always very nearly to agree.

With respect to the proportions of the latter present in different seas, it has been remarked by Dr. Marcet*, that the southern ocean contains more salt than the northern, in the ratio of 1·02919 to 1·02757, and that the proportion present in the water at the equator holds the middle place between the two.

This corresponds with my own experiments, which indicated a difference in that respect between the water of the equator taken from long. 84° 30′ east of Greenwich, and that from the Bay of Naples at a considerable distance from land, off the island of Ischia, about as 100 to 95·5; whilst the water taken from the line, in the Atlantic, in long. 21° 30′ west, was still salter, being to that obtained in east longitude as 107·5 to 100·0.

This latter result agrees with one of the conclusions deduced by Lenz†, who accompanied Kotzebue in his expedition round the world, from a series of observations made by him during his voyage.

That naturalist ascertained by numerous experiments:

1st. That the Atlantic Ocean is salter than the South Sea, and

* *Philosophical Transactions*, vol. cxii.

† *Edinburgh Journal of Science*, 1832.

that the Indian Ocean, which unites the two, is salter on the west where it approaches the Atlantic, than on the east where joins the South Sea.

2nd. That in each of these oceans there exists a maximum point of saltness towards the north, and another towards the south, the first being further from the equator than the second. The minimum between these two points in the Atlantic is found to be a few degrees south of the equator; in the Pacific it still remains to be determined.

3rd. In the Atlantic the western portion is more salt than the eastern; in the Pacific, the saltness does not appear to vary.

4th. In proceeding northwards from the point at which the saltness is at its maximum, the specific gravity of the water diminishes constantly as the latitude increases.

5th. From the equator to 45° north latitude, the sea-water, from the surface to the depth of 1000 fathoms, continues uniform in saltness.

Instruments for drawing up Water from depths.

This last conclusion, however, must not be looked upon as fully established, since the instruments, by means of which sea-water has hitherto been drawn from great depths, are considered by the best judges very faulty in their construction, and incapable of affording trustworthy results. Such was the opinion expressed by Dr. Marcet*, after examining those that had been invented up to the period at which he wrote; and such more recently was the impression of M. Arago†, who hence was led to recommend, to the navigators of the French discovery ship, the Bonite, an instrument for the same purpose of M. Biot's invention, which is on a different plan from those hitherto employed.

The description given of this contrivance by M. Arago is in itself very brief, and is unaccompanied by a plate. Possibly, therefore, I may not have understood every part of its construction, but upon the best consideration I was able to give to the subject, it appeared to me that some parts of the instrument might admit of improvement.

I consequently designed an apparatus framed on a similar principle to that of M. Biot, but provided neither with a spring to exclude the external water, nor with a stopcock and bladder to receive the compressed gas, both which objects were fulfilled by means of a small hollow cap of brass, which being attached to a conical stopper, accurately ground to the hole in the bottom of the instrument through which the water was admitted, dropped down upon this aperture when the vessel was inverted, and thus at the same time would cut off all communication with the

* *Philosophical Transactions*, 1819.

† *Annuaire*, 1836.

external water, and would receive any air, which upon the removal of the pressure might escape from the body of the vessel.

This instrument has been exhibited at the Mechanical Section, but I am loth to occupy more space in its description, until it has been put to the test of experiment in the open sea *.

Gases present in Sea-water.

The gaseous contents of sea-water, which with an apparatus of this description may be collected and examined, have not as yet received the attention they appear to deserve.

M. Arago remarks, that oxygen predominates over azote in the surface water both of the sea and of rivers †, and likewise in that of the Mediterranean even at a depth of 1000 metres ‡. This latter observation, however, is rendered doubtful by the imperfection of the means hitherto employed for drawing up water from the sea; and supposing it correct, still, as M. Arago remarks, we are left in the dark, as to whether the same law holds good at greater depths.

The determination of this point, however, is of the more importance, inasmuch as some observers have supposed the bubbles of gas, which occasionally rise up through the sea in the vicinity of volcanos, as, for example, off the coast of Sicily, to have been disengaged from sea-water; now these bubbles, unlike what would have been the case, had they been derived from the air existing in the surface-water, were found to contain a predominance of nitrogen gas §. The pressure exercised upon sea-water at great depths would also enable it to hold in solution much larger quantities of air, the presence of which, supposing it to consist in part of carbonic acid, might cause the waters to dissolve a greater amount of carbonate of lime, and thus afford a more abundant supply of that ingredient to the numerous molluscæ, that are building up extensive calcareous formations within the ocean.

Water of Lakes.

Inland seas and lakes may be divided into those which possess an outlet, and those which are destitute of one.

The water of the former commonly corresponds with that of the rivers which flow into them; that of the latter contains in general the same ingredients as sea-water, but in a state of much greater concentration.

* This apparatus has since been tried off Margate in water of 50 feet in depth, and appeared to answer perfectly.

† The most recent experiments on this subject are those of Dr. Thomson, (*Records of General Science* for Sept. 1836,) who found that the air contained in Clyde water consisted of 70·9 azote, 29·1 oxygen, and that when a mixture of the two gases was placed over water, the oxygen was absorbed much more readily and in larger quantities than the azote.

‡ *Annuaire*, 1836.

§ *Philosophical Transactions*, 1834.

Thus, 500 grains of the water of the lake Ourmia in the province of Azerbijan in Persia, contains, according to Dr. Marcet, 111 grains of salt*, and a similar quantity from the Dead Sea 192·5 grains, whereas the largest quantity present in the ocean does not seem to exceed 21·3 grains.

In quality the saline ingredients found in these lakes seem to differ very little from those of sea-water, but Lake Ourmia contained a larger proportion of sulphates, whilst the Dead Sea is found to be entirely destitute of them.

Prof. Henry Rose has lately examined the water of Lake Elton in Asiatic Russia, and has found it to possess a specific gravity of 1·27288, and to contain nearly 30 per cent. of saline matter, which approaches nearly to the quantity present in the Lake Ourmia.

In this, muriate of magnesia was the prevailing ingredient, a circumstance doubtless attributable to the extreme concentration of the solution, which is such as to have brought about a precipitation of the greater part of the less soluble ingredients. Hence rock salt is formed in thick beds, at the bottom and on the sides of this and of several other lakes adjoining the Caspian. The sea or estuary of Ohhotsk, with which are connected the brine springs of Irhoutzk, in Asiatic Russia, contains an ingredient not found in the cases before alluded to, namely, muriate of alumina, with which is associated a large quantity of other deliquescent earthy muriates, ingredients which render the salt obtained from them unwholesome†.

With respect to the borax lakes of Thibet, we possess no information capable of throwing light on the cause of their peculiar mineral impregnation.

3rdly. Water of Springs.

Proceeding next to the subject of mineral waters properly so called, I shall notice the circumstances relating, 1st, to their temperature; 2ndly, to their chemical constitution; and 3rdly, to their effects upon the animal economy.

Their Temperature.

With respect to the first point, much confusion has arisen in the application of the term "*thermal*" to springs. By some, that epithet has been applied to those only, which exceed considerably the average temperature of the springs of the country; by others, to such as reach some arbitrary point in the scale. It appears to me however, that the only precise mode of proceeding will be, to call every spring *thermal* which surpasses ever so little the average temperature of the country in which it is situated; and in constructing a scale of temperatures with regard to them, to calculate it, not by their actual warmth, but by the degree of their excess above the mean of the climate. Thus,

* *Philosophical Transactions*, 1819.

† *Annales de Chimie*, vol. xli.

a thermal spring having the temperature of 90° in this country, ought to stand higher in the scale than one of 100° in Mexico, and a spring at 70° might justly be termed thermal in the one latitude, but not in the other.

It is on this principle that I have constructed a table, which will appear at the close of this Report, conceiving, that although the exact mean temperature of the locality can in many instances be only guessed at, and in the majority must not be regarded as fully determined, still no error need arise from my mode of expression, as the ascertained temperature of each spring may be readily computed, by simply adding the number which gives the assumed mean temperature of the spot, to that indicating the excess of heat inferred to belong to the spring itself.

Now Prof. Bischof of Bonn* has remarked, that in almost every case the temperature of mineral springs (amongst which we of course do not include land springs, or waters derived from a superficial source,) is such, as places them, according to the definition just given, amongst thermal ones; and indeed the mere circumstance of a difference in this respect existing among them is in itself a strong presumption that such is the case; for it is evident that, except where a spring has its origin in certain high mountains adjoining, the coldest of the series will approach nearest to the mean temperature of the locality, whilst the remaining ones must derive their excess of warmth from some independent cause.

Thus Bischof examined about twenty springs near the Lake of Laach, and found the temperature of the coldest of them to exceed that of the place by nearly $2\frac{1}{4}$ degrees of Fahrenheit.

This rule held good even amongst the springs of countries like Hessia, Hanover, Bavaria, and Wurtemberg, where no such decided indications of recent volcanic action exist.

The same remark applies likewise to Artesian wells. Thus the temperature of forty-eight springs bored in and near Vienna, was found by observations made in November 1820, to fall between 52°·25 and 57°·2, whereas the mean temperature of Vienna is only 50°·80.

It would be important, if such observations were followed up in other portions of the globe, as well as within the comparatively limited range to which Prof. Bischof's statements apply. In some countries, for instance, where volcanic action has once been rife, as in the Hebrides and in various parts of Scotland and Ireland, one might expect some excess of temperature in the springs of the district over the mean of the climate; whilst in others,

* *Edinburgh New Philosophical Journal*, April, 1836. It is to be regretted, that a translation of the latter portion of this valuable paper has not yet been published in the above Journal.

where volcanic phænomena are of rare occurrence, as in the Scandinavian Peninsula*, Russia, and Poland, it would be well to learn, whether the temperature of springs more nearly corresponded with that of the climate, than is the case in the parts of Germany where igneous action may still be suspected. Such an inquiry would not be without its bearing upon those problems concerning the origin of thermal springs in general, which will be discussed in a subsequent part of this Report, for if thermal springs derive their temperature from a remnant of volcanic energy existing beneath, they ought to be most frequent in countries where such energy has at one time or other been manifested; whilst if they simply proceed from a generally diffused heat pervading the interior of our planet, they might be expected to appear in countries of every geological structure.

Periodical Variations of Temperature in Springs.

Independently, however, of the mere question, as to whether there be any evidence of the existence in the springs of a country of an excess of temperature beyond the mean of the climate, and the determination of this question by accurate thermometrical observations both on the air and the spring, neither of which has in most cases been done in a satisfactory manner, two points of inquiry present themselves; first, as to whether there be any periodical variation of heat in the latter from day to day, or at different seasons of the year; and secondly, whether, in the course of the ages that have elapsed since they were first known, any augmentation or diminution of temperature had occurred.

Prof. Bischof† has shown, that in some cases the variations of external temperature do manifest themselves in the thermal springs of a district; but this only happens when their excess of heat is inconsiderable.

A similar variation has been observed, as I am informed in a letter with which I was favoured from Mr. Jephson, M.P. for Mallow, in the thermal spring of that town, and it would be desirable that exact observations should elsewhere be instituted on the same point.

A variation of temperature at different periods of the year has been observed in the spring of Bourboule in Auvergne ‡, and in that of Balaruc near Montpellier.

Secular variation of Temperature in Springs.

Still more important is the question relative to the secular variation of temperature in thermal waters.

In countries where traces of former or present volcanic action are discoverable, and where earthquakes are frequent, the tem-

* I shall allude to Wahlenberg's observations on this country in a subsequent part of this Report.

† *Edinburgh Journal, loc. cit.*

‡ Lecoq, *Annales Scientifiques de l'Auvergne.*

perature of thermal springs is often inconstant. Thus in Venezuela, Boussingault and Rivero* found the waters of Mariana 64° Cent., whereas Humboldt a few years before determined it to be 59°; and that of Funcheras 92°·2, which Humboldt had found to be 90·°4 Cent.

But in the interval between these two observations had occurred the great earthquake, which overwhelmed the Caraccas and other towns situated in the western Cordilleras.

The same explanation however cannot be extended to those thermal springs which are unconnected with volcanic action, and concerning these the testimony is of rather a conflicting nature. Thus Anglada† has compared the temperature of ten springs in the Pyrenees as ascertained by him in 1819, with that determined by Carrere sixty-five years before, and in all of them found a diminution, amounting in one instance to 27°, but in the rest varying from half a degree to 7° of Fahrenheit. The same observer found an abatement of 2° in the spring of Molitg in the eastern Pyrenees after an interval of only two years.

On the other hand, it is remarkable that Berzelius‡ in 1822 found the spring of Carlsbad to possess the identical temperature which belonged to it in 1770, according to the observations of Becher, viz. 164° Fahrenheit. Yet so contradictory is the evidence, that this very spring is reported by Klaproth, at a period intermediate between the above two observations, as being 8° of temperature lower.

With regard indeed to thermal springs in general, it must, I believe, be admitted, that no observations have been yet made with thermometers of sufficient exactness to set the question at rest; and I therefore conceive, that a valuable legacy has been bequeathed to science by Prof. Forbes in the report on the temperature of the thermal springs of the Pyrenees and others, which he has lately laid before the Royal Society of London, were it only for the pains he had previously taken in verifying, and in comparing with an uniform standard, the instruments he employed.

In the absence, however, of direct experiments, we may be authorized on general grounds to presume, that the temperature of thermal springs, in countries not exposed to present volcanic operations, undergoes no sensible change during a long period of time.

If any change did take place, it would probably be from a higher to a lower degree, rather than the reverse; and as several of the thermal springs which were known and resorted to by the

* *Annales de Chimie,* t. xxiii. p. 274.

† *Mémoires sur les Eaux Minérales,* 1827, p. 65.

‡ *Annales de Chimie,* t. xxviii.

ancients, such as Aix, Mont Dor*, Plombieres, and Bath, retain at present a heat as great as is tolerable to the human body, it seems evident, that if they had been only in a slight degree hotter in the time of the Romans, they would have required to be cooled down by artificial means before they were employed for bathing, which we are not told was ever the case.

Fixed Ingredients of mineral Springs.

The same question, as the one concerning the temperature of mineral springs just discussed, may also be started with respect to the quality and quantity of their ingredients. But before we proceed to state what is known on this subject, it will be convenient to advert to a notion at one time advanced by Döbereiner†, namely, that the salts present in mineral waters bear a certain relation as to quantity one to the other.

Whether in definite proportions one to the other.

Ignorant as we are of the processes by which saline substances are formed in the interior of the earth, it might be rash to affirm, that in a mineral water which had obtained its fixed ingredients exclusively from one spot, some fixed ratio did not obtain between the respective quantities of the latter.

But it is inconceivable, that a spring, having to pass through a great extent of rock before it reaches the surface, should not more commonly find certain substances to dissolve, or become intermixed with other currents of water in its way, and that in the event of either of these things happening, the relative proportions of the original ingredients should remain as before.

If, therefore, Döbereiner were admitted to have established, that in a few special cases‡ the salts existing in a mineral water hold a certain definite proportion one to the other, probability suggests, that the circumstance is to be regarded as an exception merely, and not as the rule, and this inference, I believe, will be fully confirmed, by referring to the actual results of the analysis of mineral springs in general.

Whether the Consti-

Hence, without embarrassing ourselves with the consideration,

* At Mont Dor the very bath exists which was constructed in the time of Cæsar.

† *Ueber die chemische Constitution der Mineralwasser.* Jena, 1821.

‡ I confess myself unable to find any examples which establish Döbereiner's rule. Let us take the Carlsbad water, to which he appeals, and suppose the ingredients to be in atomic proportions. The following appear to be the nearest approximation that can be made:

				Real amount being
Sulphate of soda	15 atoms	× 72 =	1290 —	1290
Muriate of soda	9 —	× 69 =	621 —	517
Carbonate of soda	12 —	× 54 =	648 —	630
Carbonate of lime	13 —	× 50 =	650 —	650
Carbonate of magnesia..	2 —	× 42 =	84 —	86

Here are some remarkable coincidences, it is true, but how are the proportions of the minor ingredients to be reconciled to such a formula?

tuents of Mineral Waters vary from time to time.

how far such a law as that hinted at by Döbereiner could be reconciled with the idea of a gradual diminution taking place in the strength of the saline impregnation of a spring (which, according to this view, ought to proceed, if at all, in regular proportions likewise), let us simply consider the weight of evidence in favour or against the permanency of mineral springs in this respect.

Cases in which they have been observed to be constant.

On the one hand, Bischof* states, that the mineral contents of the spring of Geilnau in the Taunus mountains, as determined by himself in 1826, agree in quantity with those existing there thirty-three years before, if we believe the report of Amburger.

According to the same author, seventy-seven years have made no difference in the mineral impregnation of the spring of Fachingen in the same district, and the analysis of the water of Selters made thirty-eight years before by Westrumb corresponds very nearly with his own.

Berzelius too has shown, that the composition of the Carlsbad waters accords with the results of the analysis of Klaproth made thirty-three years previously.

Cases in which they are found to vary.

But, on the other hand, the Steinbad at Toeplitz contains, according to the last chemist, scarcely half the quantity of fixed ingredients which were present in it, according to Ambrozzi, thirty-three years before, and even then it was suspected that a diminution from an antecedent period in its saline contents had taken place.

Wurzer † found the spring of Neundorf, in the wet summer of 1833, more fully impregnated with saline matter and with sulphuretted hydrogen, than in the dry summer of 1814.

Klaproth detected in 1806 carbonate of soda, carbonate of magnesia, and silica in the mineral water of Riepoldsau. Sultzer in 1811 could not discover in it one of the above ingredients.

Westrumb in 1788 concluded, that in the Pyrmont water the saline matter was almost constant in quantity, being from 23 to 24 grains in the pint, but that the proportion of the respective ingredients varied. In March 1788 it contained rather more alkaline salt, and rather less gypsum, than in June, July, and August; but though the proportions of the respective salts might vary, the same principles always existed in it.

Struve ‡ remarks, that almost every new analysis of the spring of Marienbad affords different results as to quantity, though the total amount of saline matter, and the nature of the acids and bases present, appear invariable.

* *Vulk. Min. Quellen*, p. 329. † See Bischof, p. 331.
‡ *Kunstlichen Min. Wasser*, p. 15.

Hermann[*] shows, that in the brine springs of Halle the quantity of muriate of magnesia has gone on progressively increasing, and that of the muriate of lime diminishing, since 1798, whilst in those of Schönbeck the sulphate of soda each year has undergone a diminution.

With respect to our own mineral waters, there is a general impression, that the aperient springs, which rise so abundantly from the lias, become weaker when long drawn upon, and it is only in this way that I can reconcile the extreme discrepancy between the analyses of the same spring, at periods not very remote one from the other.

Mode of accounting for this variation.

Bischof remarks, that in some cases different results may have been obtained, owing to some variation in the circumstances under which the water had been drawn.

Supposing the well to have been just before exhausted, the water obtained ought not to be expected to be so strongly impregnated as in common, because time had not been allowed for that which had flowed in since to obtain its full complement of saline ingredients.

In this way he accounts for a discrepancy, between the quantity of sulphate and of muriate of soda, which he detected at Roisdorf in September 1824, and in April 1825; and on the same principle we may explain, why the Pyrmont water was found to be more strongly impregnated before the season of taking the waters, in May, than during June and July, the months of fashionable resort.

I may add, that if we suppose the respective salts to require different times for their solution, it may be seen, why in some cases the relative proportions of the saline ingredients have appeared to vary, whilst the total amount continued as before; for if, owing to the well having been just before much drawn upon, the salts which required the longest time for their solution existed in the water in a smaller proportion than usual, that very circumstance might enable the water to dissolve a larger quantity of the remaining ones, so as to make good the deficiency, and to render the total amount of fixed ingredients nearly the same as usual.

Method of determining this question.

Considering, therefore, the great uncertainty that exists with regard to this point in most cases, and the progressive condition of chemical analysis, which renders the results obtained at one period scarcely capable of accurate comparison with those of a succeeding one, it were to be wished, that at each of the more important mineral springs samples of the water were preserved in bottles, hermetically, or at least very closely, sealed, to be

* Bischof, p. 334.

opened at the expiration of a certain time, in order that an analysis should be made of it, as well as of the water fresh taken from the spring, by some chemist of reputation; which being done, and the results being duly registered, a similar sample of the water might be set apart for examination after the lapse of an equal interval of time.

If this method were adopted, the question at issue might soon be determined beyond the possibility of doubt.

Classification of Mineral Waters.

Writers on mineral waters have frequently attempted to classify them according to the nature of their ingredients, but these unfortunately are so often found intermixed in all conceivable proportions, that no division of them into orders founded on such a principle can be regarded as unexceptionable.

For medical purposes the most useful method would seem to be, to select, as the groundwork of the classification, those substances which stamp upon a mineral water its peculiar value as a therapeutic agent, without regarding whether they are predominant in quantity or not. Thus, as the most general division, we might distinguish them into, first, alkaline or carbonated springs, containing a certain proportion of carbonate of soda; secondly, saline, rich in muriatic salts; thirdly, aperient, containing the soluble sulphates; fourthly, sulphureous, containing sulphuretted hydrogen.

The alkaline might then be subdivided into those with, and without iron; the saline into those with, and without iodine and bromine; the aperient into those containing the alkaline, the magnesian, and the aluminous sulphates; the sulphureous into those with *free* sulphuretted hydrogen, or with the hydrosulphurets. Each of their subdivisions might then be distinguished into two sub-orders, the thermal and cold.

Such a classification might be convenient in a medical treatise, but in a scientific one we should frequently find ourselves embarrassed in assigning a place to a spring, which, like those of the Pyrenees, partook strongly of the character of the alkaline class, whilst it was at the same time sulphureous; like that of Wiesbaden, whilst allied to the alkaline ones in its vicinity, was itself strongly saline; or like the Carlsbad, Toeplitz, Bath, and Ems waters, seemed from its mineral constitution to possess an equal claim to admission into several of the classes established.

Ingredients found in Mineral Waters.

With respect to the particular ingredients which mineral waters contain, it would seem superfluous to notice in the present Report any, but those which have been either discovered, or newly investigated, within a short period.

Iron with Silica.

Iron in a new form of combination has been detected in the

springs of Lucca by Sir H. Davy*; the body combined with it being, not the carbonic or sulphuric acid, but silica.

Sir Humphry suggests, that the ochreous deposit so frequent in hot springs, as at Mont Dor, Bath, &c., may be a similar chemical compound, the iron originally existing in the state of a protoxide, but passing into that of a peroxide upon exposure to air.

Though the iron however is thrown down from the water in this condition, it does not follow that it exists there in the same, since, in proportion as the carbonic acid which had upheld it escaped, the silica present in the water might begin to exert its affinity, and be carried down along with the metal.

Iron with Muriatic Acid.

Iron has also been found by Dr. Thomson combined with muriatic acid in the mineral water of Mitchill in the parish of Nielston†, near Glasgow, and by Lachmund in the aluminous water of Buckowine in Lower Silesia‡.

Manganese.

Manganese was discovered many years ago by Becher in the springs of Carlsbad; and recent observations have shown that it is by no means uncommon either in cold or in thermal waters.

Thus it has been found in the chalybeates of Pyrmont§, Marienbad, Seltzers, and Fachingen; at Luxeuil near Paris||; at Adolphsberg in Sweden; and in several springs in Russia. Also in the thermal waters of Carlsbad and Ems; the sulphureous ones of Neundorf and Eilsen; the aperient ones of Seidschutz; and the brine springs of Kreutznach.

It has likewise been met with as a deposit from the thermal water of Popayan in the Andes¶.

Zinc.

Zinc combined with sulphuric acid has been found by Berzelius in small quantities in a mineral water at Ronneby in Sweden**, probably under circumstances similar to those, under which copper is occasionally met with in streams flowing through beds of copper pyrites.

Strontian.

Strontian has been detected in the chalybeates of Seltzer†† and Pyrmont‡‡, and in the thermal waters of Carlsbad, Konigworth, Aix la Chapelle, and Borset§§. It seems also to exist in small quantities in the springs of Bristol, it having been found, as I am informed, in a stalagmitical deposit incrusting the pipes that convey water to that city.

* *Annales de Chimie*, vol. xix. from the "Memoirs of the Academy of Naples."

† *Records of Science*, vol. iii. p. 418.

‡ Bley, *Taschenbuch*.

§ See Bley, *Taschenbuch* for the German springs.

|| *Annales de Chimie*, 1821.

¶ Boussingault, *Annales de Chimie*, 1833.

** Brandes' *Archiv*, b. xiii. as quoted by Osann.

†† Struve, *Künstlich Miner.*

‡‡ Brandes' *Pyrmonts Heilquellen*.

§§ Bley's *Taschenbuch*.

Barytes.

Traces of barytes have likewise been detected by Brandes and Kruger in the chalybeate of Pyrmont, and by Berzelius in the thermal water of Carlsbad.

Potassa and Lithia.

Potass was found in that of Toeplitz * and of Konigsworth in Bohemia; in the water of Bourbon Lancy, by Pavis †; and in one of the Cheltenham waters, by Faraday ‡; whilst even Lithia has been discovered in several, as at Pyrmont in Westphalia §; at Carlsbad ||, Franzensbad, and Marienbad, in Bohemia; and at Rosheim near Strasburg ¶.

Iodine and Bromine.

The ingredients of salt springs in general have long been understood to be the same, as those which were known to exist in the present ocean, but upon the discovery of the two new principles, iodine and bromine,—iodine abundantly in various marine productions, and more sparingly in the ocean itself; bromine less commonly indeed in the former, but in much larger quantity in the latter,—chemists were naturally led to inquire, whether the correspondence, that had before been traced between the actual and former constitution of these reservoirs of salt water extended also to the presence of the above two bodies in them both. Accordingly Angelini searched for and discovered iodine in certain springs of Piedmont **; Vogel did the same at Heilbrunn in Bavaria ††; and Turner at Bonington near Leith; whilst Boussingault met with it in a spring fifteen leagues from Popayan in the Andes, eighty or ninety miles from the sea, and 10,000 feet above its level ‡‡.

With regard to bromine, this principle was detected by Liebig at Kreutznach in the Palatinate §§; by Vogel |||| at Rosenheim in Bavaria, and at Wiesbaden in Nassau ¶¶; by Desfosses at Salins, in the Department of the Jura ***, and at Bourbon les Bains, in France; and by Stromeyer in various springs of the kingdom of Hanover †††.

Having also myself discovered bromine as well as iodine in several salt springs of South Britain, I was led to prosecute an extended examination of the principal ones, containing any con-

* Berzelius, *Untersuchung*, translated in the *Annales de Chimie*, vol. xxviii.

† *Annales de Chimie*, Nov. 1827.

‡ *Journal of Science*.

§ Brandes and Kruger.

|| Kastner's *Archiv*, b. vi.

¶ *Edinburgh New Philosophical Journal*, for Oct. 1836.

** *Journal des Mines*, vol. viii.

†† *Mineral Quellen des Baiern*, 1825.

‡‡ *Annales de Chimie*, vol. v. 1833, or *Journal of the Royal Institution*, N. S. vol. iii., from Dr. Mill."

§§ *Annales de Chimie* for 1826, p. 330.

|||| *Mineral Quellen des K. Baiern*.

¶¶ Kastner's *Archiv*, vol. xiii.

*** Ferussac's *Bull.* part viii.

††† See Schweigger's *Journal*, 1827, for "A List of the Localities in which Bromine had been detected."

siderable quantity of common salt, which are distributed through the several rocks of this country, beginning my search with the Silurian formations of Wales, and terminating it with the tertiary deposits of the London basin.

In the tabular view of the constituents of these springs given in the paper I presented to the Royal Society * on that subject, and which is now published in their *Transactions*, I showed, that although the proportions of the respective ingredients might vary, yet that as regards their quality, an almost entire correspondence must have obtained between the earliest accumulations of salt water and the existing ones, judging from the occasional presence of iodine and bromine in those of all ages.

Thus both these principles were found in waters issuing from the Silurian slates of Llandrindod and Bualt in Radnorshire, and bromine, but not iodine, in those from the coal formation of Ashby de la Zouch, Newcastle-on-Tyne, and Kingswood. Both principles exist in the springs issuing from lias, at Leamington, Gloucester, Tewkesbury, and Cheltenham; whilst in the aperient saline waters of Melksham, Epsom, and London, all of which are connected with newer rocks, iodine appeared to be altogether wanting, though traces of bromine were detected.

It remains to be ascertained by a more extensive induction of particulars than that hitherto made, whether iodine is commonly deficient in springs connected with the more recent deposits; as such a fact, combined with that of its scanty occurrence in our present seas, and its comparative abundance in strata of older date, might lead to some curious geological inferences.

The proportion of iodine to water in different springs, I found to vary from $\frac{1}{614,400}$ to $\frac{1}{21,073,900}$ part; and to the chlorine present in it from $\frac{1}{3140}$ to $\frac{1}{2,000,000}$ part.

In several of the German springs, however, the proportion appears to be much larger †. Thus, there have been found, in a pint of the salt spring of

	Muriate of Soda.	Muriate of Lime.	Muriate of Magnesia.	Hydriodate of Soda.
Hall	10·514	3·356	......	0·529
Saltzhausen	73·450	2·570	8·780	0·590
Kreutznach	59·675	11·758	4·124	0·043

In the springs I examined, the proportion of bromine to water varied from $\frac{1}{9721}$ to $\frac{1}{153,600}$ part, and to the chlorine from $\frac{1}{180}$ to $\frac{1}{1660}$.

* *Philosophical Transactions*, 1830.

† Osann, *Ueber Iod- und Brom-haltige Min. Quellen.*

The water however in which I discovered the largest quantity of bromine in proportion to its saline contents was that of Ashby de la Zouch, which contained only 179 grains of solid matter in the pint, and yet yielded more than half a grain of this principle.

This latter result has been confirmed by Dr. Ure in a memoir on these springs published in the *Philosophical Transactions* for 1833.

With respect to the salt springs of Germany, the following proportions of bromine and of other ingredients are contained in a pint of the water of each according to Osann.

	Muriate of Soda.	Muriate of Lime.	Muriate of Magnesia.	Hydro-bromate of Magnesia.	Hydro-bromate of Soda.
Brine spring of Ragozi at Kissingen	62·050	......	6·850	0·7000	......
Pandur ditto.....	57·000	......	5·850	0·6800	......
Hall..............	10·514	3·356	......	......	0·4140
Luhatschowitz	18·370	......	......	......	0·0410

The entire absence both of iodine and bromine from a few of the very strongest brine springs we possess, those for example of Droitwich in Worcestershire, as was originally stated by myself, and as has been since confirmed by Dr. Hastings in his Memoir on that subject *, may be explained by considering, that in these same waters likewise all the more soluble salts present in the sea are of sparing occurrence.

Hence the masses of salt, to which these springs owe their impregnation, may have been the first deposits from the saturated brine, and therefore contain chiefly muriate of soda.

Agreeably with this explanation we find, that the lowest saliferous strata in Cheshire consist of perfectly transparent rock salt, without a trace either of iodine or of bromine, whilst the more deliquescent muriates, together with combinations of these latter principles, are found plentifully in the clays and marls above.

It may at first sight appear doubtful, whether the saline aperients existing in the lias ought to be classed amongst brine springs, considering the larger proportion of alkaline sulphates and of muriate of lime belonging to them.

In a medical point of view clearly they ought not to be so regarded; for their most active, though not always their predominant ingredients, are those very sulphates, which do not exist, except in minute quantity, in brine springs properly so called.

* *On the Salt Springs of Worcestershire.* Worcester, 1835.

But looking to their origin, or the materials from which they are derived, they must be grouped with salt springs of the common kind, as I have shown in the memoir already quoted.

I may appeal indeed to the authority of Mr. Murchison * when I state, that these waters, like the genuine brine springs of Cheshire and Worcestershire, rise out of the new red sandstone formation. Hence it is probable, that their original constitution is analogous, but that during the passage of the water upwards through cracks and fissures in the lias clays overlying, the iron pyrites, which is so abundant in that stratum, supplies it by its gradual decomposition with the sulphuric acid found amongst its ingredients.

That sulphuretted hydrogen is generated in the vicinity of these springs, we are assured, not only from the minute quantity of this gas observed in one or two of the Cheltenham and Leamington waters, but also from the strong impregnation of the spring of Willoughby in Warwickshire, as noticed by myself, and of that of Haslar in Worcestershire, reported by Dr. Hastings †.

Now, if we grant the sulphuric acid to be derived from this source, the other differences between these saline aperients, and brine springs properly so called, will admit of an easy solution.

The sulphuric acid, acting upon the several muriates, would form with their bases those earthy and alkaline sulphates on which their medicinal qualities chiefly depend; whilst the free muriatic acid disengaged, attacking the calcareous rocks, would give rise to the production of the increased quantity of muriate of lime present in them.

With respect, therefore, to the origin of the above ingredients modern discovery has added little to the general principle laid down by Pliny, "Tales sunt aquæ, qualis terra per quam fluunt." For it seems needless to attempt tracing them further than the rocks from which the springs themselves issue.

But there are other substances of occasional occurrence that cannot be referred to this source, so immediately, or without a more particular inquiry into the circumstances of their appearance.

Of this description are two acids discovered recently in mineral waters, namely, the phosphoric, and the fluoric, an addition to our knowledge for which we are indebted to the analytical skill of Berzelius. Subsequently, the former substance has Phosphoric and Fluoric Acids.

* *Proceedings of the Geological Society,* vol. i. p. 390.

† *Salt Springs of Worcestershire,* p. 9.

been detected in the following springs amongst others, viz. the chalybeate of Hofgeismar by Wurzer, that of Pyrmont by Brandes, and that of Selters by Gustavus Bischoff; and the latter principle at Carlsbad, Selters, Ems, Wiesbaden, and Gastein.

Now though phosphoric acid is not generally stated as a constituent of the rocks through which these springs have to pass, yet I am inclined to believe, that it exists in minute proportions in very many of those that contain organic remains.

I have myself found traces of it in several secondary limestones; and its existence there may be ascribed, not merely to the coprolites which these strata sometimes envelop, and which are found more or less in formations, even as high in the series as the Silurian rocks of this country, but likewise to the bones of animals, the coverings of crustacea, and the scales of fishes * distributed through them.

In granitic rocks its presence is equally implied by the occurrence of minerals in which it constitutes the acidifying principle.

The fluoric acid exists in the teeth of animals, but it would be absurd to attribute an organic source to its presence in the strata. Its origin must be looked for in the minerals which the primary crystalline rocks contain. Thus mica and amphibole have been shown by Bonsdorff often to contain small portions of this acid †, and fluate of lime is to be met with occasionally both in primary and secondary formations.

Carbonate of Soda.

There is a class of springs, very common in some countries, though scarcely found in England, which owes its peculiar properties to the presence of a portion of soda, often associated with protoxide of iron, both of which are held in combination by carbonic acid.

Now as carbonate of soda does not exist in any of the strata with which we are acquainted, its occurrence cannot be so immediately referred to the latter; and yet the quantity drawn from the bowels of the earth by the agency of springs must be very considerable, for Gilbert ‡ calculates, that the water given out in a single year by the Carlsbad waters alone contains more than thirteen million pounds of carbonate of soda, and about twenty million pounds of its sulphate, so that we may fairly reckon the annual amount of alkali extracted, under one or the other of these forms, to be as much as 6,746,050 pounds.

* See Notice of Mr. Connell's Paper in the *Fifth Report of the British Association*, p. 41.

† *Edinburgh Philosophical Journal*, vol. iv.

‡ *Annalen*, vol. lxxiv. p. 198.

Mode of accounting for it.

But it has been observed, that mineral waters of this description occur in many instances in connexion with felspathic rocks, issuing either from primary strata, or else from volcanic materials.

Now common felspar* consists, according to Dr. Thomson, (*Outlines of Mineralogy*, 1836, vol. i. p. 295,) of one atom of trisilicate of potass, united to three atoms of trisilicate of alumina; glassy felspar of one atom of trisilicate of potass and soda, to four of trisilicate of alumina; whilst in albite, a mineral in which the ingredients are in the same proportions as in common felspar, the potass is altogether replaced by soda.

This latter alkali is therefore commonly traced to the felspathic rocks in contact with these waters; and, without going into the elaborate calculations which Professor Bischof has thought fit to institute†, by way of showing, that a single mountain of moderate dimensions,—the Donnerburg, for example, near Milleschau in the Bohemian Mittelgebirge,—contains soda enough to impregnate the Carlsbad water for the space of 35,394 years, it will be readily granted, that where a spring is in connexion with volcanic or trappean materials, there can be no want of alkali, to supply it for any conceivable length of time with that portion, which is found belonging to its constitution.

But three questions still remain to be determined, before the source of the alkali can be regarded as explained.

1st. By what process does the thermal water separate this material from its combination?

2ndly. Why does not the same force which extracts the soda, also cause the separation of a portion of the potass, with which granitic rocks at least are still more abundantly charged?

3rdly. How does the spring obtain its soda at all, in cases where it rises, either from granitic rocks containing only common felspar, and therefore no other alkali than potass, or from slates and other rocks that are destitute of alkali altogether?

The first of these difficulties has been elucidated, by the expe-

* The composition of these minerals may be expressed with greater clearness symbolically, thus:

Common Felspar $(\dot{K} + 3\,\dot{Si}) + 3\,(\dddot{Al} + 3\,\dot{Si})$,

Glassy Felspar . $\left(\left.\begin{matrix}\frac{5}{9}\dot{K}\\ \frac{4}{9}\dot{N}\end{matrix}\right\} + 3\,\dot{Si}.\right) + 4\,(\dddot{Al} + 3\,\dot{Si})$,

Albite . . . . . . $(\dot{N} + 3\,\dot{Si}) + 3\,(\dddot{Al} + 3\,\dot{Si})$.

† *Vulk. Mineral*, p. 322. *et seq.*

riments of Bischof and Struve, and by the observations of Turner.

Bischof has stated*, that even long-continued boiling in water will separate the alkali from a mass of trass or volcanic tuff, but that the process is facilitated by the presence of carbonic acid; so that he conceives the disintegration of felspathic rocks to be brought about by water impregnated with that ingredient.

Dr. Struve† of Dresden, known for his imitations of some of the most noted mineral springs in Germany, informs us, that he has extracted alkali from granite, by merely filling a tall vessel with small fragments of the stone, pouring upon it distilled water, and suffering a stream of carbonic acid gas to rise slowly through the materials, and to diffuse itself amongst the water filling the interstices between them.

Turner likewise has pointed out the action of carbonic acid and water on such substances in his Lecture on the Chemistry of Geology, which will be afterwards adverted to.

With respect to the second difficulty‡, it has been argued, that the majority of these springs arise from volcanic rocks in which glassy felspar predominates; that when they spring from granite, they have been ascertained, in some instances to contain potass as well as soda, as is the case at Carlsbad, and at Schonau near Toeplitz; and in others soda alone, as at Adolphsburg and Porla in Sweden.

It has also been remarked, that granite, in which albite has taken the place of common felspar, is more decomposable than usual§, so that if the water of a thermal spring were to traverse a rock consisting, partly of the one kind of granite, and partly of the other, it might dissolve the soda without affecting the potass.

It has been further suggested by Bischof, that in many of the analyses which have been made, potass may have been mistaken for soda, and that the former is, in fact, a much more common ingredient in mineral waters than has hitherto been suspected.

Bischof also sees a reason for deriving the alkali from the contiguous strata, in the circumstance, that the thermal springs of the Alps, which arise in general from primary rocks, contain little or no carbonate of soda.

Objections to this explanation.

To these considerations it may be replied:

1. That the quantity of potass in the Carlsbad springs is too inconsiderable to affect the argument; for it was only by a mi-

* P. 305. † *Ueber Kunst. Min. Quellen,* vol. ii.

‡ See these arguments detailed in full in Bischof's Work so often alluded to.

§ Hence sometimes distinguished as "crumbling felspar."

nute examination of the sprudelstein, the deposit from the waters, that Berzelius was able to detect its presence, whilst in the water itself much carbonate of soda, but no potass, was discernible.

2. That the detection of potass in the Swedish mineral waters only increases the difficulty of explaining, why springs, which, like those of Carlsbad, rise also from granite, contain so very small a quantity of the so-called vegetable alkali, whilst they are thus strongly impregnated with the mineral one.

3. That the alkaline springs alluded to ought to be shown to proceed uniformly from a rock containing albite, before any legitimate inference can be deduced from the alleged difference, as to the facility of disintegration, between this and other kinds of granite.

4. That although it is conceivable that one alkali may have been mistaken for the other by the older analysts, it can hardly be suspected that chemists like Berzelius, or even Anglada, could have been guilty of such an error with respect to the springs they had examined.

5. That although none of the thermal springs of the Alps, with the exception of Yverdun, are represented as containing natron, yet *all* of them are fraught with other salts of soda, and some of them with salts of potass, so that probably the earthy matter present existed in the water in the state of a muriate or a sulphate, whilst the carbonic acid, together with which they were thrown down on boiling, was united in the water with a portion of that soda, which the analyst represents as being combined with some other acid.

Thus the composition of the water of Baden, in the canton of Argau, is stated by Bauhof as follows:

In 300 ounces of the water,

Carbonic acid	48	cubic inches.
Sulphuretted hydrogen		traces.
Sulphate of lime	233	grains.
Muriate of soda	186	,,
Muriate of magnesia	51	,,
Sulphate of soda	48	,,
Lime	36	,,
Sulphate of magnesia	31	,,
Magnesia	11	,,
Extractive matter	3	,,
Oxide of iron	1	,,

Now doubtless Bauhoff here meant to express, that the lime and magnesia were thrown down combined with the car-

bonic acid; but when we perceive the large proportion of soda indicated by the analysis, it seems quite as probable that these earths existed in the water as muriates or sulphates, and that they were precipitated in the state of carbonates by the carbonate of soda, on concentrating the solution.

The same explanation may be extended to the cases of Schinznach, Weissenburg, Pfeffers, and Loueche amongst the thermal, and to Gurnigel and Engistein amongst the cold carbonated springs; whilst at Fideris, Tarasp, Luxemburg (in Thurgau), and others, carbonate of soda is stated as abundant.

But the greatest difficulty, as appears to me, is presented by the thermal waters of the Pyrenees, which are for the most part richly impregnated with soda, and yet are derived exclusively from granitic rocks, or others equally destitute of mineral alkali.

Should future observations, directed expressly to these particular points, substantiate the fact of the entire absence of potass from these springs, and that of the scanty presence of soda in the rocks with which they are connected, I apprehend the hypothesis of Bischof, plausible as it may seem, and well as it may suit the case of "volcanic mineral waters," must be abandoned, and the same theory be extended to the carbonate of soda, which we have already applied, to the boracic acid present in the Lagoni of Tuscany, and to the common salt exhaled from the craters of volcanos.

New Theory proposed.

There seems at least no absurdity in supposing, that if, as I shall afterwards attempt to show, thermal springs owe their temperature to steam and gases given out by volcanic processes carried on underneath, the former may carry with it, not only boracic acid, but also soda, which, in its passage upwards, might enter into combination with the muriatic, the sulphuric, the carbonic, or any other acid that was present.

Origin of the Carbonate of Soda in certain secondary rocks.

We need not however resort to any such hypothesis in order to account for the occasional presence of carbonate of soda in secondary strata. In salt lakes which become nearly dry in summer, a portion of natron will often result, either from the decomposition of the muriate of soda by calcareous matter, in consequence, as is supposed, of the operation of the law of Berthollet with respect to the influence of the mass, or, as is more probable, from the conversion of sulphate of soda by organic matter into sulphuret, and the decomposition of the latter by the earthy carbonate. To one or other of these causes we ascribe the natron of Hungary, and perhaps that existing in certain mineral waters of Bavaria, said to be remote from volcanic or trappean rocks.

Soda with-

In the cases hitherto mentioned, the alkali has been supposed

to be united with carbonic acid, and this is stated as being the case in the majority of the mineral springs that contain it. out Carbonic Acid in Springs.

Longchamp * however asserts, that in certain of the thermal waters of the high Pyrenees, as at Bareges, Cauterets, St. Sauveur, and the like, the soda exists in an uncombined form, and that to this must be attributed the peculiar action it exerts upon the cuticle, causing the water to feel soapy and unctuous to those who bathe in it.

Anglada † questions this assertion, on the faith of experiments made by him on some of these waters that had been sent him, (as he says,) carefully corked; but trials of such a description cannot of course be put into competition with others instituted, as those of M. Longchamp appear to have been, on the spot, granting both the individuals to be competent authorities on the point.

I may also state, in confirmation of Longchamp's evidence, that being at Barege some years ago, I tested the water fresh drawn from the well with a solution of baryta, and found no cloudiness to be produced till after it had stood some little time exposed to the air, whilst after the addition of lime-water a still longer period elapsed before any indication of carbonic acid appeared.

The experiment was tried with the same success at St. Sauveur.

Dr. Turner has also stated ‡, that the springs of Pinnarkoon and Loorgootha in India, which were examined by him, contain soda uncombined with an acid; and Faraday § has confirmed the statement of Dr. Black, who long ago reported the soda of the Iceland springs as being in that condition.

Now, as in many of these springs no carbonic acid is present, and as the alkaline salt existing in the rock from which they emerge is not a carbonate, but a silicate, we can better understand the possibility of the soda being found in the condition stated, even if, adopting the theory of Bischof, we refer it to the rock in connexion with the spring; whilst those who lean to the contrary hypothesis, and trace the alkali to the very seat of the volcanic action which causes the high temperature, will be able still more readily to account for its appearance in that form.

Silica, its origin in Springs.

Silica appears to be an universal ingredient in thermal springs, and is perhaps present in more minute quantities even in those of all temperatures.

* *Annales de Chimie*, vol. xxii. † *Mémoires*, p. 302.
‡ *Edinb. Journal of Science*, No. xvii. p. 97.
§ *Barrow's Visit to Ireland in* 1835.

Its existence in the epidermis of most monocotyledonous plants proves, that it must be held in solution by the descending sap; and the latter, in whatever way it may be supposed to be elaborated within the texture of the plant, can only obtain its earthy principles from the water which happens to encircle the roots.

How far explained.

On the fact of its solution in water, Turner has lately made some observations in his Lecture on the Chemistry of Geology*.

He has shown, that water must have the property of dissolving silica, by contrasting the chemical composition of felspar with that of the porcelain clay which results from its decomposition.

The former, as he represents it, consists of one atom of trisilicate of potass, with one atom of silicate of alumina, in the proportion of nine of silica to one of alumina; whilst porcelain clay consists of seven atoms of silica to two of alumina, or as three and a half to one†.

Hence water had carried off in some way all the potass, and eight and a half out of twelve proportionals of the silica, leaving *all* the alumina and the remainder of the silica untouched.

Now the solution of the silica may be referred in general to its being exposed, at the moment of its disengagement from its existing combination, to the joint action of water and alkali.

But it seems to admit of question, whether the latter be really essential to the process.

I have myself found a coating of a substance like hyalite in the fissures of a rock in the island of Ischia, through which hot vapours were constantly issuing, and am at a loss to refer it to any other cause, except the gradual solution of silica in the first instance by the steam, and its precipitation afterwards from it.

I have also found, in a soft state, coating fissures in a trachytic rock, near Schemnitz in Hungary, what appeared to be silex hardening into the condition of hyalite, a mineral occurring in many places near,—an observation in which I find myself to be anticipated by M. Beudant.

Dr Wollaston indeed had observed, and Dr. Turner confirms

* *Phil. Magazine*, 1833, vol. iii. p. 20.

† Represented symbolically thus:

$$(\dot{K} + 3\,\dot{Si}) + (\dddot{Al} + 9\,\dot{Si}) \text{ Felspar,}$$

$$(\dddot{Al} + 3\tfrac{1}{2}\,\dot{Si}) \text{ Porcelain Clay;}$$

so that $(\dot{K} + 3\,\dot{Si}) + 5\tfrac{1}{2}\,\dot{Si}$ have been removed, and only $3\tfrac{1}{2}\,\dot{Si}$ remain.

the truth of the remark, that steam under high pressure becomes a rapid solvent of alkaline silicates.

The latter chemist even found*, that glass exposed to the vapour issuing from an high-pressure engine was rapidly corroded, and that the silica taken up was again deposited in a beautiful stalactitical form.

It however remains open to further inquiry— How far unaccounted for.

1st, What is the solvent of silica in springs which contain no free alkali:

2nd, By what means it is held in solution by the sap of vegetables:

3rd, What are the circumstances which interfere with its solution by artificial means.

With reference to this subject, I may allude to an interesting memoir by Professor Fuchs, on the amorphism of solid bodies†, as throwing some light upon the question as to the solubility of silex, and illustrating the influence in this case of mechanical obstacles upon chemical affinities.

He has shown, that silica exists in minerals in two conditions, a crystallized and an amorphous one, and that in the latter it is much more readily acted upon by solvents, than in the former‡.

Dr. Turner also found, that whilst glass was rapidly dissolved by high-pressure steam, rock crystal remained unchanged.

It would have been curious to determine, whether under such circumstances, amorphous silex (such as opal) would continue untouched.

Muriatic and Sulphuric Acids.

Muriatic and sulphuric acids in a free state are found only in springs connected with volcanos, to which they are obviously referable.

Boracic Acid.

Boracic acid, which has been detected in a thermal spring of the island of Ischia, and more abundantly in the water of the Lagoni of Tuscany, seems also to be a volcanic product.

It is well known as resulting from volcanic operations in the Lipari Islands and elsewhere; and its appearance in their craters

* *Proceedings of the Geol. Soc.*, vol. ii. p. 95.

† *Edinb. New Philos. Journal* for April, 1835.

‡ A recent traveller in Iceland (Krug von Nidda) in Karsten's *Archiv*, vol. ix., remarks, "that the solubility of the silica in such considerable quantity in the hot springs of Iceland, remained for a long time a puzzling phænomenon, until that property was discovered, which it has in common with phosphoric acid, viz. of forming two isomeric modifications, of which one is insoluble in water and in acids; the other is soluble in both." This may be true; but the statement must be regarded as a mere expression of a fact, not as the explanation of it.

becomes intelligible, when we reflect, that although dry boracic acid continues fixed at high temperatures, yet when steam is passed over it at a red heat, a portion of the acid is always sublimed, as I have myself ascertained by experiment.

Whether the same explanation will apply to the case of the lakes of Thibet, whence so large a quantity of borate of soda is obtained, future travellers must determine.

Nitric Acid. Nitric acid, united probably with potass (this alkali being found along with it), sometimes occurs in the springs of large towns, as observed by Pagenstecher* in those of Berne, and by Berzelius in those of Stockholm†.

There is also a tract in Hungary, included betwixt the Carpathians and the river Dran, throughout which all the springs are said to be impregnated with this ingredient‡.

The spontaneous production of nitre, wherever organic matter in a state of decomposition remains in contact with calcareous rocks, or with earth containing carbonate of lime, may sufficiently account for its existence in such springs as these, which probably owe their origin rather to superficial than to deep-seated causes.

It remains, however, to be inquired, whether the same explanation can be extended to the waters of St. Alban, Dep. de Loire §, and of Münchhof|| in Germany, in both of which nitre is said to be present, and that not, as in the former cases, in variable, but in fixed proportions.

Ammonia in Springs. Can we attribute to the same decomposition of organic matter the presence of ammonia in certain mineral waters?

Scherer¶ mentions a sulphureous spring in Courland, which contains it in union with the muriatic acid; and Osann** one at Raab in Hungary; whilst Berzelius†† notices its occurrence in the mineral waters of Porla, united with a peculiar acid, the crenic, which will be noticed presently.

Longchamp also states, that there are traces of it in some of the thermal springs of the Pyrenees; but he does not state in what state of combination it occurs.

Professor Fischer‡‡ of Breslau has detected it in combination with carbonic acid in the thermal water of Warmbrunn, in

* *Uebersicht der Bestandth. der Brunnen der Stadt Berne.*
† Osann, vol. i. p. 92. ‡ *Ibid.*
§ Patissier *Manuel des Eaux Minérales*, p. 280.
|| Schweigger, *Journal*, vol. xlv.
¶ Page 180. ** Page 85.
†† *Phil. Magazine*, vol. vi. p. 239.
‡‡ Groefe, *Jahrbucher für Deutchlands Heilquellen*, 1836.

Silesia; Wetzler* in the cold spring of Krumbach, in Bavaria; and Kastner† in that of Kissingen, in the same kingdom. The water of Clinton, near New York, is likewise stated to contain five grains of carbonate of ammonia in the gallon‡.

It may, indeed, be suspected that this principle is in reality of still more frequent occurrence, and that chemists have often overlooked its presence, in consequence of having driven it off by the heat which, in analysing the water, they had in the first instance applied.

Now in many of the above instances, I should be disposed to ascribe the occurrence of ammonia to causes of the same description, with those which I suppose to have given rise to it when found issuing from the spiracles of volcanos, especially as it is remarkable that, although the evolution of nitrogen gas and of ammoniacal compounds in a few rare instances occurs simultaneously, yet for the most part the two in a manner take each other's place, the volatile alkali being abundant in active volcanos, where nitrogen gas is not common, and scanty and unfrequent in the thermal springs of primary countries, where nitrogen gas is so generally disengaged.

My own views respecting the formation of ammonia in volcanos are stated in my Memoir on the eruption of Vesuvius in 1834, published in the *Philosophical Transactions*, and will be elsewhere referred to in this Report; but I should be unwilling to extend them beyond the case of those springs which, judging from their temperature, appear connected with volcanic action, and from their purity, or freedom from organic matter, cannot be supposed capable of generating ammonia by any process of animal or vegetable fermentation.

To these latter causes I should of course refer the presence of ammoniacal compounds in those waters, which, from their contiguity to large cities, or from their own impure condition, seem to contain in themselves the elements from which the volatile alkali might be generated.

Whilst speaking of ingredients which may be suspected to arise from the presence of organic matter in springs, I must state, that formic acid is said to have been detected in the waters Formic Acid. of Prinzhofen near Staubing§, and at Brunnen near Emkirchen, four or five leagues from Erlangen||, both in Bavaria; and acetic Acetic Acid.

* Kastner's *Archiv*, vol. x.

† *Archiv*, vol. xxvi.

‡ Silliman's *Journal*, vol. xviii.

§ Pattenhofer, in Kastner's *Archiv*, vol. vii.

|| *Archiv*, vol. xxiii.

acid in a spring at Craveggia in Piedmont, by Vauquelin; and also in those of Ronneberg*, and Bruchenau in Bavaria.

Crenic and Apocrenic Acids.

More recently Berzelius has described two new vegetable acids in the springs of Porla† in Sweden, to which he has given the names of the crenic and the apocrenic, both derived from an organic matter present in the water, the crenic first, the apocrenic from the other by the action of oxygen.

Crenic acid does not crystallize, but its solution in water concentrated to the consistence of a syrup is almost colourless. When dried in vacuo it splits in all directions, and its taste is then distinctly acid and astringent. Though a weak acid, it decomposes the acetates, and combines with the alkalis and alkaline earths. Most of them are insoluble in water, but the protocrenate of iron is soluble.

The apocrenic acid imparts a brownish colour to water, in which it is but slightly soluble. Its salts resemble the crenates, but are either brown or black, and are insoluble in alcohol.

They combine with hydrate of alumina when digested with it, and form a colourless solution.

These two acids were found in several chalybeate waters in Sweden, and may be separated from the ochre which they deposit by boiling it with potass.

The crenic acid ‡, or one much resembling it, has since been detected by Professor Fischer of Breslau in the mineral spring of Landeck in Silesia §.

Organic matter in Springs. Glairine, or so called animal matter.

The above acids may possibly have some connexion with an organic substance found in most thermal and many cold springs, which has excited much speculation, and been supposed to possess important medicinal qualities. We owe the first accurate information respecting it to Bayen ||, who, in 1765, published an account of the mineral water of Luchon, in the Pyrenees, in which he discriminated this flocculent matter from the sulphur also present.

In 1786 Dr. Willan¶ described a white mucous substance existing in the waters of Croft, in the county of Durham, which

* Döbereiner in Kastner's *Archiv*, vol. xvi.

† *Phil. Magazine*, vol. vi. p. 239.

‡ The crenic acid has lately, it is said, been found to be an ingredient of the Bergmehl of Lapland, which the natives in times of scarcity mix with their flour, considering it to contain nutriment. This material is stated to be chiefly made up of the outer shells of fossil infusoria, together with some animal matter probably derived from their internal substance, and of the acid alluded to.—*Phil. Mag.* for April 1837.

§ *Jahrbucher Deutschlands Heilquellen.*

|| *Opuscules Chemiques.*

¶ *On Croft and Harrogate Waters.* London, 1786.

had likewise been confounded with the sulphur given out by the same springs.

In a recent visit to Croft I found this substance in abundance, and traced it as far as the water flowing from the spring retained its sulphureous odour, but not when the latter was dissipated.

Mr. Dillwyn, in his work on British Confervæ*, notices the same as occurring, not only at Croft, but likewise at Harrogate in Yorkshire, and Llanwrtyd in South Wales, all of them springs of similar composition, and determined the substance to be a Conferva, which, from its whiteness, he denominated *Nivea*.

In the thermal spring of Bath a Conferva of a different species abounds, which, from its colour and appearance, used to be called Bath sulphur, although not a particle of this latter principle exists in these waters.

It seems, therefore, to be generally agreed, that the mucous matter found in the mineral waters of this country is owing to the generation of organized beings; but with respect to that met with amongst thermal and other springs in various parts of the Continent, no such correspondence of opinion subsists.

On the one hand, Bory St. Vincent, in a memoir "Sur la Botanique des Eaux†," appears to attribute it in every instance to the growth of a certain class of Confervæ, to which he has given the name of Anabaina.

To this opinion also M. Delarive, in his memoir on the springs of St. Gervais‡, adheres; and I am informed by Professor Decandolle, that the waters of Acqui in Piedmont were examined by him with reference to this point, and that he always found himself able to detect in the so-called *animal matter* which abounds there an organic structure.

Many chemists, on the other hand, have taken up a contrary view of this subject, amongst whom I may instance Professor Anglada|| of Montpellier, who, in his elaborate work on the mineral waters of the Eastern Pyrenees, has given a detailed description of its properties, as presented in the localities he has specified.

The substance in question he denominates *glairine*, from its glutinous or jelly-like appearance. It was observed by him in cold as well as hot sulphureous springs, in all nearly fifty in number. It occurs in flocks, in threads, having the character of mucus, or of membrane, in compact concentric coats or Described.

* P. 54.

† *Bulletin de la Société Philomatique*, et *Dictionnaire Classique d'Histoire Naturelle*, art. Arthrodiæ.

‡ *Bibliothèque Universelle*, vol. xxii.

|| *Mémoires pour servir*, &c., vol. i.

zones, in parallel fibres, and pendent in a stalactitical form from caverns.

With respect to colour, glairine is of various shades of either white or red, the latter being found generally in the hottest springs.

It gives out a mawkish smell, succeeded after a little time by one of a more repulsive kind, arising from its decomposition. In its chemical properties it bears most resemblance to animal mucus, and disengages azote when acted upon by nitric acid. M. Anglada afterwards shows that the thermal waters which deposit glairine, also contain a portion of the same in a state of chemical combination, the largest quantity, however, present not exceeding one third of a grain to the pint.

As the water cools, a portion of this matter separates, and may then sometimes be perceived floating in it in minute semi-transparent flocks of a mucous character.

Accounted for. It is this latter circumstance, which principally leads him to suppose, that the glairine exists formed in the interior of the earth, and that the mineral water is merely instrumental in bringing it to the surface.

In order to explain how such a product could arise, Anglada appeals to an experiment of Döbereiner's, who found, that when steam was passed through an iron tube containing heated charcoal, a gelatinous matter frequently made its appearance. He also notices the production of a fatty-looking substance by Berard, on passing through a red-hot tube a mixture of carbonic acid, olefiant gas, and simple hydrogen.

It is with great diffidence that I dissent from the views of M. Anglada, who has undoubtedly paid more attention to this remarkable substance than any other individual that could be mentioned, and question the fact which he so confidently affirms, of the occurrence of specimens of glairine in the Pyrenean springs and elsewhere, to which it would be impossible to assign an organic origin †.

* Vol. xiii. part i.

† In further corroboration of my views I may quote the authority of the naturalist Turpin, who has also examined two specimens of the so-called Baregine, the one from Barege, the other from Neris. An investigation of them under the microscope proved, that chemists had been confounding under the same name, several very different organic products, and that the so-called Baregine from Neris had no resemblance in its origin or constitution to that from Barege.

The former, which he obtained from Robiquet, was nothing else than the Nosthoc or Conferva thermalis, already so often described. That from Barege, which he got from Longchamp, consisted of a gelatinous transparent and almost colourless substance, without any apparent mark of organiza-

Nevertheless, the observations I have myself made in some of the very same localities as those visited by M. Anglada, the substance of which is given in the *Linnean Transactions**, lead me to conclude, that the glairine of M. Anglada is frequently, and therefore justify me in suspecting that it may be always, generated at or near the surface, by the rapid growth of certain lower tribes of organic beings.

At Greoulx I remarked large patches of it hanging from the sides of a highly inclined rock, over which the water of that thermal spring had descended.

Now if it had been a chemical precipitate from the waters, this could not have happened; but supposing it an organic matter, whose growth was favoured by the temperature or the constitution of the spring, its presence therein is not more difficult of explanation, than that of Algæ on the face of a precipitous cliff.

Moreover, the specimens of glairine which I collected always presented under the microscope, in some part or other, an organic structure.

It is indeed true, that I detected traces of what appeared to be the same substance in the water of Barege fresh drawn; but it being admitted that, like many other organic matters, glairine is slightly soluble in water, and more so in hot than in cold, its presence there may be explained, if we only suppose that its growth proceeds, not only in the open air, but likewise in those fissures and cavities underground through which the water has to pass.

Berthier† also, who has considered this subject in a memoir on the Hot Springs of St. Nectaire, declares that he has never found this organic matter in waters taken from the fountain-head, and corked directly afterwards, but that it makes its appearance after a very short exposure of the water to air and light. Though this remark may not be universally true, the larger deposits of glairine, I believe, always arise in water that has been exposed to the atmosphere.

In short, there seems no insurmountable difficulty, in the way of our attributing the existence of glairine everywhere to the growth of organic bodies, such as should reconcile us to the

tion. It is a slimy mass formed out of a great number of parts, which for the most part arose from the decomposition of plants and animals, especially Infusoria.

It is plain from this, how necessary it is that the chemist should ascertain the homogeneous nature of any substance which may be suspected to be organic, before he submits it to chemical analysis.—Poggendorff's *Annalen*, 1836.

* Vol. xiii. part i. † *Annales des Mines*, vol. vii. p. 215.

adoption of an hypothesis, so strongly opposed to probability as that advocated by Anglada.

Those who are sceptical as to the possibility of so very rapid and apparently so spontaneous a production of organic matter, as that which takes place in these thermal waters, should peruse a memoir in Schweigger's *Journal**, and also one more lately published in Poggendorff's†, by the celebrated Ehrenberg, on the blood-red appearances observed at various periods, covering the surface of lakes and stagnant pools, spreading over various articles of food, or descending in rain from the heavens.

The former of these papers proves the rapidity with which bodies of this kind are generated; the latter establishes, that in almost every case in which the particulars have been carefully investigated, the phænomenon has resulted from the generation of some kind or other of organic matter.

There is, indeed, an observation of Gimbernat‡, which ought perhaps not to be passed over, although I am not myself disposed to attribute any weight to it. I allude to his finding a substance similar at least to glairine, if not identical with it, in the condensed vapours proceeding from the fumaroles of Vesuvius. But when we recollect, that the apparatus in which this steam was collected had been allowed to remain for one or two days without being disturbed, during which time the water was freely exposed to atmospheric influences, under circumstances peculiarly favourable to the growth of Confervæ, there seems no necessity for supposing the organic matter found in it to have been derived from the entrails of the volcano.

I have myself collected, on several occasions, the vapours that arose from the spiracles of this very same mountain, after the great eruption of 1834, as I have stated in the memoir which I published in the *Philosophical Transactions* for 1835, but in no instance could I discover any organic matter.

Red ferruginous matter.

In the thermal springs of Vichy, and in some other localities, where sulphur is not present, an organic substance has been observed floating on the surface §.

Longchamp, in his account of that spring, states that it is intermixed with carbonate of lime, together with which I found entangled within its meshes a portion of peroxide of iron; and

* For 1827; extracted from a work by Dr. Sette, entitled *Mem. Storica Naturale.* Venezia, 1824.

† Translated in *Edinburgh New Philosophical Journal* for 1830.

‡ *Bibliothèque Universelle,* vol. xi.

§ Vauquelin, *Annales de Chimie,* vol. xxviii.

in the memoir already referred to*, I explained the mode in which I conceived these substances to find their way to the surface.

It seemed to me probable, that each portion of warm water, from below, as it rose to the surface of the well or reservoir which received the overflowings from the spring, would set at liberty a little of the earthy and ferruginous matter it had held in solution, in consequence of the disengagement of some of the carbonic acid with which it had been surcharged whilst under a greater pressure.

But this solid matter, being entangled in the Confervæ floating on the surface, would be prevented from becoming precipitated; and would form, by degrees, an earthy and ochreous crust upon the water.

But Professor Ehrenberg, of Berlin, to whom we are indebted for so many striking discoveries with respect to recent and fossil infusoria, has thrown quite a new light upon this subject, having ascertained, as he lately assured me, that this red matter is in fact composed of the outer sheaths or coverings of a multitude of little infusorial animalcules, which appear to possess the singular property of secreting oxide of iron as well as silica, and hence thrive only in chalybeate waters, which afford them the material for the coat of mail which invests their softer parts. This at least he finds to hold good with respect to the red ferruginous matter which collects in certain chalybeate waters in the neighbourhood of Halle, and I have little doubt that the same will apply to the similar incrustation found in the water of Vichy, &c. Ehrenberg's researches respecting it.

Thus, whilst one class of beings requires, as we have seen, for its existence the presence of sulphur in such a state of combination, as is found to be absolutely destructive to other kinds of life, another class secretes iron, a substance equally unsuited for the nourishment of the great majority of animals; as if it were intended, that there should be no class of inorganic productions which did not minister to the wants, and favour the production, of a corresponding order of organized creatures.

It seems worth inquiry, whether the red ochreous sediment found by Davy in the baths of Lucca may not have arisen from a similar cause, and be made up of an accumulation of infusoria; and likewise whether the colours which belong to certain specimens of rock-salt, which are sometimes of a deep-blue, but more generally red, are not owing to certain vegetable or animal matters. Colouring matter of waters explained.

* *Linnean Trans.*, vol. xvii.

Ehrenberg*, in his journey into Siberia, observed a rose-red colour in the salt lake Elton, in the steppe of Astracan, which did not appear to belong to the water, but faded on drying; and I perceive in a recent journal, that Mr. Pajean, in his travels in Tuscany, remarked that the red substance, which is produced on the surface of water charged with marine salt in that country, is the result of an accumulation of an enormous quantity of small crustacea, of one or two lines in length, having nearly the form of a craw-fish, which live very well in brine of 15 degrees, but die when the water is further concentrated.

It is stated, that M. Darcet brought similar crustacea from certain lakes in Egypt which are charged with natron.

With respect to the blue colour sometimes observed in rock-salt, it is possible that the same kind of explanation may apply to it. I was once inclined to imagine, that it might be caused by a compound of iodine with some vegetable principle, analogous to starch, or producing with the former a similarly coloured compound; but I could detect no iodine in the specimen, and failed to reproduce the violet tinge, when the salt had been dissolved in water and crystallized a second time.

Now Ehrenberg relates, that a lake in the South of Prussia in 1819, produced a particular colouring matter very similar to indigo, which appeared to be of a vegetable nature; and Scoresby† mentions, having in 1820 observed, that the water of the Greenland sea was chequered with alternate green and blue stripes, and that these colours were produced by minute animalcules of the medusa kind.

Gases evolved from springs.

The gases disengaged from mineral waters have been investigated by Bischoff, Anglada, Boussingault, Longchamp, and others.

Boussingault‡ remarks, that the elastic vapours which rise so abundantly from the thermal springs of the Andes, consist of carbonic acid and sulphuretted hydrogen, and the same observation applies to most of those in connexion with volcanic formations elsewhere.

Carbonic acid.

Of these two gases, the one most copiously evolved is carbonic acid, which, as is well known, produces those extensive deposits of *calc-sinter*, that are so common in caverns exposed to the drippings of water, and of arragonite§, which are of rather rarer

* On Blood-red Water.

† *Arctic Researches.*

‡ *Edinburgh New Philosophical Journal*, vol. xv. 151.

§ See a paper in the *Annales de Chimie*, June, 1834, on the presence of Arragonite in an Artesian well at Tours. I possess some also deposited from the spring of St. Nectaire in Auvergne.

occurrence in such situations. The particular circumstances determining the production of the one rather than the other form of calcareous spar, appear to be still unexplained, for stalactitical arragonite does not appear to contain any other essential ingredient than carbonate of lime, and is now supposed to arise from a difference of form in the integrant molecule of that base*.

Another point requiring elucidation, relates to the absence of carbonate of magnesia from stalactites arising from dolomitic rocks.

Is it, that the acidulated water first dissolves the carbonate of lime, before it attacks the atomic compound of lime and magnesia, or that the attraction of carbonic acid for the former exceeds that which it exerts for the latter earth?

With respect to the extrication of carbonic acid from the earth, I have myself pointed out† the enormous quantity evolved in the vicinity of Naples, as at Torre del Annunziata, in which and in other places it frequently destroys vegetation, and likewise near the axis of the Apennine chain, midway betwixt the active volcano of Vesuvius, and the extinct one of Mount Vultur, at the Lago d' Ansanto‡. Its quantity.

Bischof § has described its extrication, from the various mineral waters connected with the volcanic mountains of the Rhenish provinces, and likewise from dry fissures in the ground, where its escape is recognised by the stunted vegetation, and by finding a number of small animals suffocated round the spot.

Lecoq || and others have mentioned the remarkable erosion produced in the rocks contiguous to the mines of Pont Gibaud in Auvergne, owing to the presence of this gas in the water which oozes through the rocks encircling them.

Brandes and Kruger, in their account of the mineral waters of Pyrmont ¶, have shown, that the extrication of carbonic acid is by no means limited to the spot from whence the chalybeate

* Mr. Crosse, amongst the experiments which he detailed at the Bristol Meeting of the British Association, stated, his having found that calcareous spar was formed on limestone, and arragonite on slate, by the drippings from the same cavern, and that he was even able by the slow action of electricity, to produce each of these minerals from the same water, charged with carbonate of lime, according as he placed it on a piece of limestone, or of slate.

† *Edinburgh New Philosophical Journal*, 1835.

‡ *Memoir on the Lake Amsanctus, and on Mount Vultur in Apulia,* printed by the Ashmolean Society of Oxford, 1836.

§ *Vulkanische Mineralquellen*, p. 251.

|| *Annales Scientifiques de l'Auvergne*, and Ferussac's *Bulletin*, vol. xvi.

¶ P. 155, et seq. See also Brandes' work on the Mineral Waters of Meinburg. Lemgo, 1832.

springs of that watering-place arise, but is observed for some distance round, wherever fissures, natural or artificial, exist.

Thus, a cavity having been made by some workmen for quarrying stone, it was found, that the air within became charged with from 36 to 48 per cent. of carbonic acid, which rose in the cavern to different heights at different times.

Its variations. These writers report, that in winter the gas never attained so high a point as at other seasons; that in the morning, some hours after daybreak, and in the evening, soon after sunset, the mephitic air had reached its maximum, whilst at midday, when the sun shone into the cave, it was very low; that the evolution of gas was greatest before the breaking out of a storm, but diminished after it had begun; that the variations of barometric pressure seemed to exert no influence upon the phænomenon, except so far as they were connected with the occurrence of a storm; that it was greater during hot weather than cold; in calm than in windy; in a moist state of the atmosphere than in a dry one. A similar remark has been made with respect to the disengagement of carbonic acid in Auvergne*, as that recorded as to Pyrmont, the quantity given out being so large during storms, and during the prevalence of a westerly wind, as to render some of the mines unworkable.

Kastner † also alludes to the variation as to quantity, both in the water and the carbonic acid, observed at Kissingen in Bavaria, and attributes it in both cases to a difference in atmospheric pressure, the water being forced out by the gas, and the escape of the latter checked, in proportion to the weight of the atmosphere above.

According to Mayen, the springs of Bochlet have a regular ebb and flow, both as to the amount of water and of gas. The greatest difference in quantity corresponded with the interval between the first and last of the moon's quarters. At Fachingen ‡ the quantity of gas evolved is said to be greatest just before sunrise, and least about two or three o'clock after midday.

Its amount. The amount of carbonic acid given off has in a few instances only been determined §.

Trommsdorff found the quantity evolved from a fissure at Kaiser Franzenbad, near Egra, to amount to 5760 Vienna cubic

* Fournet *Annales Scientifiques de l'Auvergne*, vol. ii. p. 241; or Ferussac's *Bulletin*, for 1829.

† *Archiv*, vol. xvi.

‡ Kastner, *Archiv*, vol. i.

§ See G. Bischoff in *Edinburgh New Philosophical Journal*, 1835, from Poggendorff's *Annalen*.

feet in 24 hours, whereas the water in the same time emitted was calculated at 259 cubic feet; and Bischoff notices one spring which gave out in the same time 4237 c. f., the water being 1157 c. f. and containing 1909 cubic inches of this gas, and another which evolved of gas 3063, and of water 3645 cubic feet, which contained of gas 871.

Such statements are worth recording, as enabling our successors to ascertain whether there be any secular variation in the quantity of gas evolved; and it is therefore to be regretted, that Bischoff has not mentioned the names of the springs which he had examined with reference to this point.

The uninterrupted manner in which the carbonic acid rises up through the spring is explained by Bischoff, by supposing it held in chemical solution by the water at a great depth, and therefore under an enormous pressure.

Such a supposition would enable us to understand the trifling irregularities observed in the flow of gas, without imagining that the state of the atmosphere above has any direct influence upon the energy of the volcanic operations below, since the barometric pressure, the relations to moisture, &c. of the air surrounding the spring, might favour at one time more than at another the escape of gas from the spring, or its diffusion through space. Some have supposed*, that the water of the spring is forced upwards by the elasticity of the confined gas, but Bischoff justly remarks, that the flow of the former is too equable for any such thing to happen.

An explanation of this kind can only be resorted to in such cases as those of the Sprudel at Carlsbad, and at the Geysers in Iceland, where the spring appears, as it were, by fits and starts.

Yet in these cases the phænomenon may, perhaps, be more readily accounted for by the extrication of steam in cavities connected with the fissure through which the spring rises, as was first suggested by Sir G. Mackenzie†. Dutrochet, however, has described an intermitting spring in the Jura, which he ascribes with more reason to a periodical evolution of carbonic acid gas; though, even here an accumulation of gas taking place in a cavity connected with the spring, may have been competent to produce the phenomenon.

That Nitrogen escapes occasionally from thermal springs, is by no means a new discovery, for it was remarked by Priestley Nitrogen.

* Berthier, *Annales de Chimie*, vol. xix.

† *Travels in Iceland.*

at Bath, and by Pearson at Buxton, before the commencement of the present century.

In thermal springs.

More recently it has been observed issuing from almost all the sulphureous thermal waters of the Pyrenees*; and I have shown, that not only has it in many instances been mistaken for carbonic acid, but also that it is commonly evolved wherever thermal waters exist†.

Even when the prevailing gas emitted is carbonic acid, I find that a small quantity of residuary air is present, which consists in general of oxygen and nitrogen, but with a much smaller proportion of the former than that present in the atmosphere.

The volcanic district of Ischia affords the only example that has occurred to me, of a number of thermal springs lying together, not one of which evolves nitrogen‡.

In this case, however, we may remark, that no kind of air whatever is emitted from the waters, which therefore would seem to derive their heat, not from any volcanic processes going on at present, but from their contiguity to a mass of rock heated by antecedent eruptions.

In corroboration of this view I may state, that several springs on the skirts of Vesuvius, where volcanic operations are actually proceeding, give out nitrogen, though in much smaller quantity than they do carbonic acid; as for example, the thermal water of Torre del Annunziata, and the cold spring of Castellamare.

From the Thermals connected with extinct volcanos, azote is emitted, though for the most part in inferior quantity, than it is from springs associated with primary, or with intrusive rocks of older formation.

Its amount.

The quantity of this gas returned to the atmosphere through the medium of thermal waters is evidently considerable. I measured that emitted from the King's Bath, in the city of Bath§, nearly every day for a month during the autumn of 1833, and found that its average quantity was 267 cubic inches per minute, or 222 cubic feet in the 24 hours.

The gas consisted of 97 per cent. of nitrogen, and of 3 per cent. of oxygen, with a variable quantity of carbonic acid. Since this period, the sinking of a well in a remote quarter of the town through the lias to the depth of 250 feet, from which water rose of a temperature but little inferior to that of the

* Anglada, *Mémoires*.

† On Hot Springs and their connexion with Volcanos, *Edinburgh New Philosophical Journal* for 1832.

‡ Daubeny, on a Spring at Torre del Annunziata near Naples.

§ See my Paper on the quantity and quality of the Gases disengaged from the Thermal Springs at Bath, *Philosophical Transactions*, 1834.

Public Bath*, was followed, not only by a diminution in the supply of water at the latter, but also in the amount of gas emitted, which, according to the accurate observations of Mr. George Spry, of Bath, made in the beginning of August in this year†, appears not to average at present more than 170 cubic inches per minute, whilst the quantity of water discharged at the original spring, was reduced from 120 gallons to 75, in the same interval of time.

Thus the relation between the decrease of gas and of water kept pace very nearly one with another; for,

$$\text{as } 150 : 222 :: 75 : 111.$$

The slight excess of gas may have arisen from the more scrupulous manner, in which Mr. Spry prevented its escape from all the apertures in the bath, excepting those from which he collected it, than had been previously done by myself.

I have since estimated the amount of gas emitted from the thermal spring of Buxton at about 50 cubic inches per minute, and find that M. Longchamp determined the quantity at one of the springs, Cauterets in the Pyrenees, as being about 7·1 cubic inches, whilst he calculates that of the water given out by the same during an equal space of time at 1584, or nearly 226 times the amount.

The above are nearly all the observations we at present possess, with respect to the quantity of nitrogen emitted from thermal springs, though it would be desirable to obtain in every instance an exact register of this, as well as of the quantity and temperature of the water itself, as affording us the data for determining at some future time, whether any secular variation is taking place in the quality of each spring in these several respects.

In the table, therefore, at the close of the present Report, I have registered in two separate columns all the observations I could collect, on the quantity of gas and water emitted within the space of twenty-four hours by the springs named.

It is worth remarking, that an evolution of nitrogen gas is not altogether peculiar to thermal waters. In cold springs.

I detected it issuing pretty abundantly from a spring near Clonmel, which possessed the common temperature of those in the neighbourhood; another emitting the same has been de-

* M. Arago, in his *Annuaire* for 1836, mentions, that the same falling off of the hot spring of Aix, in Provence, took place in consequence of the sinking of a contiguous well, but it is remarkable that in this case the water of the latter was cold.

† Viz. in 1836.

scribed, as occurring near Inverkeithing in Scotland, by the Rev. W. Robertson*, and I have been informed of a third in Shropshire by Mr. Murchison.

Oxygen.

In one or two cases oxygen is said to predominate in the air evolved, as Robiquet says is the case at Vichy; but as he adds, that it is only found, after the water has been standing in the reservoir long enough to be covered by a vegetable slime, I conceive this gas to have arisen from the decomposition of carbonic acid within the tissue of the plant, under the influence of solar light.

Carburetted hydrogen.

Carburetted hydrogen has in many instances been observed to issue from springs, as well as from clefts in the earth, as at the Pietra Mala on the Apennines, and at St. Barthelemi near Grenoble, where the gas, when once kindled either by accident or design, maintains a continued flame, until pains are taken to extinguish it.

It has also been observed in many parts of the world to issue copiously from salt springs, as at Medonia in the State of New York, in China, &c.; and a curious proof that the salt, with which these springs are impregnated, had been deposited under pressure, is afforded by the fact, that at Wielichza in Gallicia its cavities contain carburetted hydrogen in a condensed state, so that on immersing a lump of this salt in water, a series of small detonations is heard during its solution, in consequence of the sudden expansion of the gas on escaping from its prison.

It is an interesting circumstance, to find this phænomenon continuing in the very spots, in which it was observed during the periods of Grecian history.

I have quoted in another place†, an instance of its occurrence among the Chimariot mountains of Albania, where ancient writers speak of a nympheum as existing, by which they meant to express, that a stream of inflammable gas had there been observed.

Sulphuretted hydrogen.

The same permanency seems also in some cases to be the attribute of sulphureous waters; for the hot springs of Bithynia, which modern travellers describe as impregnated with sulphuretted hydrogen, appear from the accounts of Greek writers‡ to have been similarly constituted nearly two thousand years ago.

These, however, which are *thermal* sulphureous springs, pro-

* *Edinburgh New Philosophical Journal*, 1829.

† Memoir on the Bath Waters above quoted.

‡ See the Poem "Περι τα εν Πυθιοις Θερμα," extracted from the Greek Anthology in my *Description of Volcanos*, 8vo, 1826.

bably derive their origin from a totally different cause, to that which impregnates cold ones with this same principle.

The latter in some instances undergo, within a very short period, a material alteration in point of strength.

Thus a sulphureous spring at Willoughby, in Warwickshire*, yielded me in the autumn of 1828, 16·9 cubic inches of sulphuretted hydrogen to the gallon.

In the April following, I could detect only 12·65 cubic inches, and in the autumn of 1834 only 5·2.

Whilst on this subject, I may mention, that Professor Anglada of Montpellier†, has satisfied himself by a detailed examination of the sulphureous springs of the Pyrenees, that no one of them contains sulphuretted hydrogen in a free state, but that in every instance this principle is united to an alkaline base, with which it constitutes an hydrosulphuret.

Finding this to be the case so generally, he has proposed a classification of sulphureous springs founded on this principle, arranging them, according as they contain the above gas in a free state, or combined with one, or two atoms of a base.

By applying the same reagent (the arsenious acid,) which M. Anglada had employed, I was led to conclude, that the springs of Aix la Chapelle and Borset were similarly constituted, and indeed such would necessarily be the case, whereever the soda in the water was not impregnated with carbonic acid, nor could there well exist in it any free sulphuretted hydrogen, until the whole of the alkali was thus saturated.

Hence in affirming that the gas of the Pyrenean springs always occurs in this state of combination, M. Anglada has (apparently unconsciously) confirmed the statement, which he questions, as to the existence of caustic soda in the water.

We have already considered whether under ordinary circumstances mineral springs are subject to vicissitudes, either as to temperature, as to the quantity and quality of their fixed and gaseous constituents, or as to the amount of water discharged. Influence of earthquakes upon springs.

It will be proper, however, before proceeding further, to notice what has been observed, with respect to the influence exerted upon them in any of the above respects by earthquakes, which are stated in some cases to have affected particular springs in an extraordinary manner.

During an earthquake in 1768 at Vienna, the spring of Baden became more copious than before, and the evolution of sulphuretted hydrogen more abundant‡.

* *Philosophical Magazine*, Jan. 1835. † *Mémoires pour servir, &c.*

‡ Kastner's *Archiv*, vol. v.

An earthquake in 1692 is said to have affected the spring of Spa in a similar manner; and one that happened in the surrounding district communicated to the spring of Bagneres de Luchon an increase of temperature.

But these are effects produced by earthquakes in the vicinity of the springs; more remarkable is the influence exerted upon them by similar subterranean movements taking place in distant quarters.

Thus during the great earthquake of Lisbon, the hot spring of Toeplitz in Bohemia, betwixt the hours of eleven and twelve in the day, is recorded to have become turbid, and then to have gushed out so copiously as to overflow the well. The water assumed a red tinge, and was suspected to have become hotter. At the same time the hot spring of Pesth in Hungary is said to have shown a similar increase of temperature.

This sympathy with the subterranean movements of a distant quarter will appear less extraordinary, when we recollect, that the same earthquake is said to have been felt by the workmen in the mines of Derbyshire.

In other cases, the connexion of the spring with the subterranean movement has been evinced, perhaps as decisively, by the opposite effect occurring.

Thus in 1660, in consequence of an earthquake, the thermal waters of Bagneres de Bigorre were for a short time suspended; during one that occurred at Naples, the Sprudel at Carlsbad is stated to have remained tranquil for six hours; and in the great earthquake of Lisbon, that of Aix in Savoy ceased to flow.

Lastly, in a few instances, the existence of a thermal spring has seemed to act as a safety valve, and to secure the immediate locality from those natural convulsions which affected the neighbourhood. Thus an earthquake which shook the whole district around was not felt at Carlsbad itself, and the same remark has been made at Wiesbaden.

Springs exerting a peculiar action upon the animal œconomy.

I have now stated the more recent additions that have been made to our knowledge as to the contents of mineral springs; but the undertaking would be incomplete, if I passed over without comment those, which, though not known to contain any peculiar chemical ingredient, seem nevertheless to produce certain decided effects upon the animal œconomy.

For to refuse credence to the reports given by medical men with respect to the salutary or injurious effects of a particular water, merely because the chemist can discover in it no active principle, would seem a proceeding not less unphilosophical, than that of which our predecessors were guilty, in treating as fabulous the accounts given of stones that had fallen from the

sky, because they did not understand how such ponderous masses could have continued suspended in it. And on the other hand, granting that a spring possesses peculiar virtues, we must suppose that it differs, either in its mechanical, or chemical properties, from the rest.

Accordingly those springs, which are believed on good authority to possess medicinal virtues, ought properly to find a place, not merely in a professional treatise on the subject, but also in one that affects to consider it scientifically.

Most countries afford examples of springs, that appear almost chemically pure, to which medicinal qualities have been accorded: thus Gastein in the Saltzburg, and Loueche in the Swiss Alps, amongst thermal waters; and Malvern in England, amongst cold ones*, are very sparingly charged with mineral matter, and what they contain consists of ingredients apparently not calculated to exert any action upon the animal system.

How far the reputation enjoyed by these springs may be owing to other causes, such as the purity of the air, the change of diet, mode of living, &c., it is for the enlightened physician to inform us, and an interesting field of physiological inquiry seems to be open to him, in examining the effects exerted upon the system by that long-continued immersion in warm water, to which it is the practice of invalids in several of these watering places to resort†.

It is remarkable, that a very large proportion of those celebrated warm springs lie at a considerable elevation. Thus Gastein is 3100 feet above the sea, Loueche 4400, and Pfeffers 2128 feet; now one may easily imagine, that the exhalation from the surface of the body, and the activity of the functions thereon dependent, may be much promoted by the practice of the invalid, of remaining alternately immersed, in water of so high a temperature, and in so rarified an atmosphere. If, however, after taking this and other circumstances into account, the testimony, in favour of some specific action derived from the spring itself upon the animal œconomy, should seem unexcep-

Causes of their agency considered.

* Dr. Hastings, in his *Illustrations of the Natural History of Worcestershire*, 1834, states, that its efficacy is found to be very considerable in arthritic, calculous, dyspeptic, and scrofulous cases.

† Dr. Gairdner doubts the statement I had on a former occasion made on this point; but I can assure him, from personal observation at Loueche, and by quite sufficient testimony as to Gastein, that in both these baths it is the practice to remain immersed, for periods of time, varying from four to ten hours, during the process of cure. At Buda too, and at Glasshutte in Hungary, the peasants continue in the public baths for a length of time, that would quite astonish an English physician.

tionable, the chemist ought to consent to regard this action as indicative, of undiscovered principles, or modes of combination.

In the presence of iodine and bromine.

Thus certain salt springs in Piedmont had acquired from time immemorial a reputation in the cure of goitre, which the nature of their then known mineral impregnation would not explain.

Recent investigations have, however, shown, that these springs contain a small quantity of iodine, the very principle now found most efficacious in this and other glandular disorders.

The superior efficacy attributed to the waters of Cheltenham and Leamington over mere artificial solutions of sulphate of soda, &c. of the same strength, was difficult of explanation, until chemical analysis had shown that, in addition to the more common ingredients, these springs contain portions of two active principles, iodine and bromine, wanting in the imitation of them.

In like manner chemists, in the pride of half knowledge, may often have smiled at the faith reposed in the water, of Ashby-de-la-Zouch in Leicestershire, and of Kreutynach, in the Palatinate, both which, until lately, appeared to be little more than mere saturated solutions of common salt.

But the advance of science has shown, that these two springs are precisely the ones most fully impregnated of any perhaps known with salts of bromine, and therefore most highly charged with the properties of that active principle.

In the absence of air.

It has long been a vulgar notion, that goitre arose from drinking snow water, and this opinion, which was derided by men of science, seems to be in some measure substantiated by the recent researches of Boussingault in the Andes*.

That naturalist commences by showing, that the goitre of the above elevated region can arise, neither from the humidity of the climate, as had been supposed by some, nor from the nature of the earthy ingredients of the springs, as had been imagined by others.

He then observes, that persons who habitually employ as their beverage water devoid of its due proportion of air (whether that deficiency be owing, to the rarefaction of the atmosphere on the high table land on which it lies, or to the circumstance of its being immediately obtained from the melted snow of the mountains) are subject to this disease, whilst persons who take care to aerate their water before drinking it, as may be done by those residing at a moderate elevation, by merely exposing it to the atmosphere for 30 or 40 hours previous, escape the deformity.

For the same reason, a river, which at a high level appears to

* *Annales de Chimie,* 1833.

cause goitre, has no such tendency at a lower one, so soon, that is, as its waters have become duly aerated in the progress of their descent.

In like manner, water which rises from calcareous rocks, or which has become stagnant in lakes, has a tendency to produce goitre, not by reason of its solid contents, but owing to the absence of the usual quantity of air.

Boussingault also relates the extraordinary fact, that those provinces, which are provided with salt containing iodine, are not affected with goitre, whilst in others, where the salt is destitute of that principle, the disease is endemic.

In their electrical condition.

There has likewise been an attempt lately made by a German physician* to mark a difference in the electrical condition of one of those springs, which, though almost chemically pure, seemed nevertheless to possess active properties.

He states, that the water of Gastein conducts electricity better than common water would do. Such a statement, however, cannot receive any credence, until all the details of the method, by which a result so paradoxical was arrived at, have been submitted to the judgement of scientific men.

Kastner had previously endeavoured to establish the same in the case of the waters of Wiesbaden, but the fallacy of his experiments is now generally admitted.

In their capacity for heat.

Equally fanciful appear the opinions of those, who attribute to natural thermal springs a greater capacity for heat than belongs to artificially prepared waters of equal temperature, and who maintain that they cool more slowly in consequence.

M. Longchamp, in France, by experiments on the waters of Bourbon; Professor Gmelin, of Heidelberg, by similar ones on those of Baden-baden; Reuss, Neumann, and Steinmann by some on the springs of Carlsbad; and Schweigger and Ficinus by others on those of Toeplitz, have exposed the fallacy of this notion; and have shown, that in reality no difference exists in this respect between the one and the other†.

Analysis of mineral waters.

Let us next proceed to consider the improvements, that have been lately introduced into our methods of analysing the solid and gaseous constituents of mineral waters.

General principles.

Most chemists are by this time familiar with the simplification upon the plan of proceeding, which we owe to Dr. Murray‡ of Edinburgh, in consequence of his having pointed out, that as the salts existing in a spring need not be the same with those we obtain on evaporation, and as salts viewed as incompatible may

* Dr. Pettenhofer. † Consult Bischoff, *Vulk. Mineralq.*, p. 364.

‡ *Transactions of the Royal Society of Edinburgh.*

coexist in a state of weak solution, the analysis of a mineral water consists in nothing more than in determining the nature and amount of the several acids and bases which it contains. But Berzelius has further contended*, that everything beyond this, which the chemical analysis professes to give, is a matter of hypothesis, and that in concluding the salts, actually present in the water, to be necessarily the most soluble compounds, that could be formed out of the acids and bases present, Murray went further than he was justified, either by experiment or analogy, in doing.

The Swedish chemist, on the contrary, contends, and apparently with much justice, that, consistently with the views of Berthollet on the influence of the mass, we ought to suppose as many salts to exist in a mineral water, as can be formed out of the constituents present, whilst the proportion, in which these salts exist, is a point which we cannot obtain data for calculating, until we are able to estimate numerically, the relative force of affinity subsisting between the ingredients.

According, therefore, to the received views on this subject, the chemist ought in strictness barely to set down, as the results of his analysis, the respective weights of the acids and bases present.

If he does more than this, and professes to combine these principles into salts, it should be understood, that he acts merely in conformity with existing usage, and in order to convey to the public the impression, that those waters, in which he has found such and such acids and bases, act upon the system in a manner similar to that, which the salts he states to exist in them are considered calculated to do.

Particular improvements.

With respect to the particular improvements introduced into this department of chemical analysis, I may particularize the following:

To distinguish barytes or strontites from lime;

A solution of sulphate of lime has been proposed as a test for barytes, or strontites, in a mineral water.

If either of these bases exists therein, a precipitate is formed, whereas, if lime alone is present, no effect takes place on the addition of this reagent.

barytes from strontites.

An easy method of separating barytes from strontites has been invented by Liebig†, who treats the mixed solution with iodate of soda, this forming, an insoluble precipitate with the baryt, but a soluble compound with the strontian.

Another method‡ has lately been proposed for the same object, namely, that of adding neutral chromate of potass to the

* In his Analysis of the Carlsbad water, *Annales de Chimie*, vol. xxviii.

† Already noticed in Mr. Johnson's Report.

‡ *Philosophical Magazine*, March 1836.

mixture of strontian and baryt, whereby a soluble salt is formed with the former, and an insoluble one with the latter.

The precipitated chromate of barytes must be heated to redness before it is weighed.

The common method of detecting lithia in mineral waters is to precipitate it by phosphoric acid, a little phosphate of soda being first added to the solution, in order to make sure of the whole of the phosphate of lithia being thrown down. Lithia.

Kastner* proposes as an improvement, that the solution should be neutralized by sulphuric acid, and then reduced to dryness.

Alcohol will take up the sulphate of lithia without affecting the other sulphates, and the solution on being evaporated, and then redissolved in as small a quantity of water as possible, may have its lithia thrown down, in combination with phosphoric acid, by phosphate of soda.

An elegant method of detecting nitric acid was proposed by Dr. Wollaston. It consisted in adding to the liquid a few drops of muriatic acid, and a little gold leaf, which latter will be dissolved if nitric acid be present †. Nitric Acid.

Döbereiner ‡ has lately suggested another method, which enables us to determine also the amount of nitric acid, even when in small quantities.

He mixes the suspected liquid with an equal quantity of concentrated sulphuric acid, and introduces the mixture into a graduated tube, placed over quicksilver. A slip of copper is then added, and the mixture warmed. Sulphate of copper is thus formed, and an amount of azote collected equivalent to that of the nitric acid present.

A more convenient plan of conducting the experiment would seem to be, that of heating the suspected liquid in a glass tube, containing a little metallic copper and sulphuric acid, and receiving the gas over mercury.

I have already noticed the probability that ammonia has often been overlooked in our analyses of mineral springs. To detect it, sulphuric acid should first be added to the water, which may then be concentrated, and evaporated in a water-bath, after which the addition of quicklime will separate the ammonia, and render it sensible both by its odour and alkaline reaction. Ammonia.

The received method of estimating the amount of bromine, Bromine.

* *Archiv*, vol. xvi.

† Becquerel has proposed an electro-chemical method of effecting the same object founded on the same principle. *Traité de l'Electricité*, vol. iii. p. 325.

‡ Berzelius, *Jahresbericht*, 1832, p. 162.

when present in a water, together with chlorine, is stated in my work on the Atomic Theory *.

It is nothing more than an application of the method suggested by M. Gay-Lussac for calculating the proportions of soda and potass, to the case of bromine and chlorine, and labours in common with it under the objection, that the inference is deduced, not from a single experiment, but from a comparison of at least two; and that a very trifling inaccuracy in either, being multiplied in the calculation founded on them, vitiates the whole result.

It would be well, therefore, if a direct method of determining the same could be hit upon; and for this reason I set down one suggested by Lowig, which has already found a place in Professor Johnston's Report on Chemistry, published in the first volume of our Reports.

The dried mixture of chloride and bromide is to be heated in a stream of chlorine, so long as any bromine appears to be disengaged. The chlorine and bromine which pass over are received into a solution of caustic potass, by which chloride of potassium and chlorate of potass, together with bromate of potass, are produced.

Having neutralized the potass with nitric acid, nitrate of silver is added to precipitate the chlorine and the bromic acid.

The precipitate, after being washed, is introduced moist into a bottle, and barytic water added. A soluble bromate of barytes is thus formed, whilst the chloride remains untouched. The solution being poured off, the excess of barytes is separated by carbonic acid, and the bromate of barytes is thus left in a state of purity.

Dr. Osann† has lately suggested another mode of separating these two principles.

It depends on the greater volatility of chlorine than bromine, and on the circumstance, that chloride of silver becomes of a violet colour after exposure to light, whilst bromide of silver is rendered greyish black.

He therefore expels the chlorine and bromine by means of sulphuric acid, slowly distils over the two, and makes them pass into a solution of nitrate of silver. The precipitate is from time to time tested by exposure to light, and when found to assume the appearance belonging to bromide of silver, that which comes over is set apart, and reckoned as such.

In order to obviate the objection, arising from the circumstance, that there is an intermediate period when the chlorine

* *Introduction to the Atomic Theory*, p. 89. The same method was followed by Dr. Ure in his analysis of the Ashby water; *Phil. Transactions*, 1834.

† Poggendorff's *Annalen*, 1831.

and bromine come over together, Osann proposes to stop the distillation, exactly at the point at which the precipitate is an equal mixture of the two acids. The deficiency of bromine in the solution is thus compensated for by the chlorine obtained. It is evident, however, that a very practised eye would be required, in order to obtain correct quantitative results by such a method as the above.

The same author proposes to separate iodine from chlorine, by causing the mixture to pass over in a state of vapour into a solution of potass, and then precipitating it with arsenious acid or arseniate of ammonia.

The iodine unites with the arsenic, which latter is precipitated by sulphuretted hydrogen. This being got rid of by oxide of lead, the iodine is obtained by uniting it with silver.

Oxides of iron.

Henry Rose* has proposed a new method of distinguishing between the protoxide and peroxide of iron.

When muriatic acid is added to a mixture containing both these oxides, the protoxide is converted into a protochloride, the peroxide into a perchloride.

Now metallic silver robs the latter of its half-atom of chlorine, converting it into the protochloride, and hence the increase of weight in the silver added, enables us to calculate the amount of peroxide of iron originally present.

Another method for the same object has been proposed by Fuchs †. It consists in digesting the solution of protoxide and peroxide in an acid, with carbonate of lime or of magnesia, by either of which the peroxide is precipitated, whilst the protoxide remains untouched.

This peroxide is obtained in a state of mixture with the earth and acid employed, and must be separated from both by the ordinary means.

The only difficulty consists, in preventing the weight of the precipitate from being increased during filtration, in consequence of the conversion of some of the protoxide into peroxide.

In order to prevent this as much as possible, the precipitate should be washed repeatedly with warm water, before the supernatant liquor is thrown upon the filter.

Organic matter.

For the detection of organic matter in mineral waters, Dr. Davy has suggested the employment of a solution of nitrate of silver‡. The blackening, which usually takes place in this fluid upon exposure to light, is attributable to the presence of organic matter; for if care be taken to purify the water, light produces no change.

* Berzelius, *Jahresbericht*, 1832, p. 164.

† *Jahresbericht*, 1832, p. 164.

‡ *Edinburgh New Phil. Journal*, 1828, p. 129.

When, however, this test is employed, we must first assure ourselves that no chlorides exist in the solution; for chloride of silver, which would be formed, is blackened by the sun's rays, even though no organic matter be present.

Gases. For determining the quality and amount of the gases chemically combined with a mineral water, Mr. Walcher* suggested a modification in the common apparatus, with a view of obviating the error likely to arise from a portion of the water being driven over by the ebullition.

In his experiments, the glass globe containing the water to be boiled was connected, air-tight, to a little phial, from which proceeded a sigmoid tube, passing under mercury, or into the vessel containing the substance intended to absorb the gas.

Let us suppose, for instance, that our object is to ascertain the amount of nitrogen and oxygen which a water contains. In that case we fill the phial with carbonic acid, and the graduated tube with solution of potass. The air expelled by ebullition, together with a portion of the water itself, entering the phial, expels the air, which passing into the tube, is robbed of its carbonic acid by the potass.

After the experiment is over, the air remaining in the phial may easily be transferred into the jar, and the water which came over may be passed back again into the glass globe, in order that it may be treated like the rest.

In this manner, perhaps, a somewhat greater degree of accuracy may be attained, than where a glass globe with a sigmoid tube alone is employed.

But I conceive that the utility of Mr. Walcker's plan will be chiefly felt where the object is to ascertain the amount of sulphuretted hydrogen, or of carbonic acid in a mineral water, by boiling it, and passing the gases over into a solution calculated to absorb them.

In such cases, if any portion of the water comes over with the gas, the result is entirely vitiated; and to prevent this, there seems to be a convenience in the intervening bottle, which, however, where sulphuretted hydrogen is expected, should be filled with some gas not containing oxygen.

Sulphuretted hydrogen. After all, however, the simplest mode of ascertaining the amount of sulphuretted hydrogen is by adding directly to the water some reagent, which precipitates it in a state of combination.

Mr. Richard Phillips, in his analysis of a spring near Weymouth†, has employed the nitrate of silver, which appears to be

* Brande's *Journal of Science* for 1828.
† *Phil. Mag.*, vol. iii. p. 158.

preferable to any other substance, as the only combinations formed are the chloride and the sulphuret, of which the former is soluble in liquid ammonia, whilst the latter is not acted upon by it.

I have already stated, that M. Anglada considers the sulphuretted hydrogen of the Pyrenean springs to be combined with an alkali. In order to determine whether this be the case or not, the test he employs is a solution of arsenious acid*, which gives a yellow precipitate with the free acid, but does not affect solutions of the hydrosulphurets†.

Azote is usually detected by negative trials, but an ingenious method of directly proving its presence has lately been suggested. Azote.

This is, to melt a piece of potass in contact with a slip of zinc in the air suspected to contain it, suspending over the two a piece of turmeric paper, moistened.

The water of the potass will thus be decomposed, its oxygen passing over to the zinc, and the hydrogen being liberated. The latter, at the moment of its separation, unites with any azote that may be present, forming ammonia, which produces its characteristic effect upon the test paper.

The fabrication of factitious mineral waters, being entirely dependent on the knowledge we may possess of their chemical constitution, seems to claim a place immediately after the consideration of their analysis. On factitious mineral waters.

The subject is one which has excited considerable interest on the Continent, in consequence of the labours of Dr. Struve of Dresden, who has devoted himself, for a number of years past, to the imitation of those natural springs which possess the highest reputation amongst his countrymen.

To do this completely, considerable skill in manipulation, and a minute attention to several apparently unimportant circumstances, are found to be requisite.

As the first step of the process, the water intended to be mineralized, must be impregnated with the same amount, of carbonic acid, and the other gases which its natural prototype possesses; and, in order to effect this object, the whole of the atmospheric air existing in the water must be previously expelled, and the carbonic acid added, under a pressure, neither greater nor less, than that to which it is subjected in nature.

All this time the fluid must be kept at the exact temperature

* *Mémoires pour servir*, &c., vol. ii.

† Prof. Johnston mentions in his *Report on Chemistry* another method, p. 460.

which the natural spring maintains, and access of air during the continuance of the process must be scrupulously prevented. This done, the same fixed ingredients must be presented to the water, and no one principle omitted, however small may be its quantity in nature, or however inert it may in itself be, it being recollected that the introduction of a fresh substance, by the affinities it exerts, alters, according to the Berzelian doctrine, the proportions of all the salts previously existing in the water. Nor is this all, for it is necessary that the water should be maintained at the same temperature and under the same pressure till the very moment of drinking it.

Similar precautions must be adopted during the act of bottling, the bottle being previously filled with carbonic acid before the water is passed into it: for if the vessel were already occupied by atmospheric air, much of the carbonic acid existing in the water would be expelled, and, consequently, a portion of the earthy or metallic ingredients be thrown down.

To fabricate, therefore, a successful imitation of a natural spring, a more complicated apparatus is employed than was formerly believed requisite, and the water must be made to pass through various successive operations, before the process is wound up by the addition of the saline ingredients by which it is mineralized.

When thus prepared, the factitious water will coincide with the natural one in taste, smell, specific gravity, and other physical properties. The gas-bubbles will rise in the same form, and spontaneous decomposition will take place within the same period and to the same extent.

The mineral waters prepared by Struve really seem to fulfill these conditions in a great degree, and have stood likewise the test of a rigorous chemical analysis, without the detection of any deviation from the original.

Their pretensions, indeed, have been occasionally sneered at, as might be expected, by the physicians and chemists, who have taken under their patronage the interests of any one of those natural waters, for which the artificial ones are offered as substitutes.

"Dr. Struve," says one*, "professed to prepare genuine Carlsbad waters, prior to the analysis of Berzelius, who detected in it six or eight new ingredients. He went on doing the same after the discoveries of this great chemist had been announced. Perhaps ten years hence we shall find half a dozen more principles in the water. But no matter, for we shall always find at Dr. Struve's a supply of the true and genuine Carlsbad water."

* Peez, *Traité des Eaux de Wiesbaden*, p. 93.

This is scarcely candid criticism. It may be admitted, indeed, that an artificial mineral water can at best be only a near approximation to the natural one, and that we can never be absolutely sure of having arrived at a knowledge of all the contents of the latter.

Yet even if we take the very case of the Carlsbad waters, which are quoted against Struve, how minute is the difference between the analysis of Berzelius, and that of Klaproth, which he had previously taken as his guide.

Struve* indeed calculates, that during a month's use of these waters, an individual who drank ten glasses full of them each day, would not have consumed quite five grains of those ingredients, which Berzelius's analysis shows to have been overlooked, namely,

Of fluate of lime	2·58	grains
Carbonate of strontia	0·77	„
Phosphate of lime	0·18	„
Carbonate of magnesia	0·67	„
Subphosphate of alumina	0·26	„
Total . .	4·46	„

When, therefore, we have a mineral water prepared by art, which possesses the same apparent physical properties belonging to the one which it is intended to imitate, and when the best analysis, which the existing state of chemical science admits, confirms this identity, there is surely no such antecedent improbability, in the idea of its possessing similar medicinal virtues, as should indispose us to receive the reports of medical men, when they assure us that in this latter respect also the same correspondence subsists†.

Still, however, as the natural spring will always deserve a preference, I cannot think that Dr. Struve is happy in fixing, as the main seat of his operations, upon Dresden, a city lying not very remote from any of the springs which it has been his business to imitate.

It is rather in the branch establishments which have been set up under his auspices, at Moscow, Warsaw, Königsberg, and Brighton, that the value of his method will be appreciated, since the carbonated waters which he prepares are scarcely to be met with in these countries, lying as they do beyond the range of those volcanic phænomena, which extend from the

* *Ueber kunstlich. Mineralwasser.*

† Half the substance of Struve's work consists of the statements of different physicians as to the efficacy of his artificial waters.

mountains of the Taunus to those of Bohemia and Silesia, and of which this class of springs are among the consequences.

Products of springs.

Before I conclude this portion of my subject, it may be proper briefly to notice, to what extent mineral waters appear to have affected the geological structure of certain parts of the earth.

Trivial as this influence may seem at present to be, yet it will be sufficient to refer to Mr. Lyell's well-known work, as establishing the position, that no inconsiderable portion of the crust of the globe, in volcanic countries at least, is attributable to the deposits which they have occasioned.

Calcareous.

Without pretending to describe the vast accumulations of travertin formed by carbonated springs, in Tuscany, in the Campagna di Roma, in Hungary, &c., I shall merely remark, that the resemblance, which some varieties of this deposit bear to the materials of older calcareous rocks is so great, and the passage from one to the other so imperceptible, that we are naturally led to suspect the latter to have been often produced in the very same manner.

Thus some varieties of travertin are undistinguishable in hand specimens from marble, as that formed by the waters of Civita Vecchia in the Campagna *. Others, like that near the town of Nonette, on the right bank of the Allier in Auvergne, might be mistaken for the Juratic limestone †; and the shelly limestone, now forming at the bottom of many lakes, bears the most complete resemblance to certain tertiary deposits ‡.

Even the concretionary structure of the limestone of Sunderland, a rock, which, though existing in the magnesian limestone formation, and in the midst of a powdery variety of dolomite, is itself almost wholly calcareous, is imitated by the spheroidal masses of travertin that occur at Tivoli and at Carlsbad, and may have resulted from the same gyratory motion of its component parts during their deposition, to which Mr. Lyell has ingeniously attributed the concentric circles of the latter deposit. The absence of magnesia confirms this suspicion.

In the ocean it is probable that mineral springs fulfill a still more important office—that, namely, of supplying with calcareous matter those Molluscæ which are building up extensive coral reefs; for, as I observed many years back §, the muriate of lime which the ocean contains, would long ago have been exhausted by the operations of these animalcules, supposing them to have the power of decomposing it, and of appropriating its

* Lyell's *Geology*, vol. i. p. 198.

† Lecoq and Bouillet, *Vues et Coupes d'Auvergne*, p. 131.

‡ Lyell, *Geol. Trans.*, 2nd Series, vol. ii. p. 73.

§ *Inaugural Lecture on Chemistry*, Oxford, 1824.

base, unless we assume this salt to have existed originally in sea-water, in such a proportion as would have been seemingly incompatible with marine life.

Mr. Lyell has also justly remarked, that the same volcanic agency, which has raised the bed of the ocean, sufficiently to admit of its serving as a basef or the coral reefs which form within it, also, by the carbonic acid which it causes to be emitted, occasions a larger quantity of that calcareous matter, which they require, to be dissolved by the water in their vicinity. Gypseous deposits are likewise often produced by springs of the present day, as noticed, with respect to those of Baden near Vienna by Prevost, and that near the lake Amsanctus by myself.

How far the beds of sulphur which occur in volcanic districts, and the sulphate of lime which is associated with most beds of salt, can be referred to the same, will be discussed afterwards; but we must take care not to confound (as some writers appear to have done,) the creative effects of mineral waters, with their decomposing agency. The latter is illustrated in the deposits of the mud-volcanos, as they are called, of South America, where vast masses of matter, chiefly argillaceous, derived from felspathic rocks decomposed by water and acid vapours, are washed down into the low country, and there constitute extensive beds. Argillaceous.

The rocks described by Menge *, as formed by hot springs in Iceland, are probably of the same description, for it is impossible to follow this author in that portion of his statement, in which he represents basalt, lava, and trap porphyry, as in the act of being produced in them. He appeals indeed to the fact of his extracting from the midst of a boiling marsh, a mass of matter, which when broken, exhibited the characters of basaltic lava in the centre, and towards the surface passed gradually into red and grey mud; but it seems just as easy to explain this, by the decomposing influence of the water extending gradually from the circumference to the centre, as by the contrary process taking place in the reverse direction.

The siliceous formations actually deposited at the present time by springs, appear to be comparatively insignificant, the most important being those of Iceland, and of St. Michael in the Azores. It is probable, however, that under the sea, where the influence of heat, and the chemical affinity of alkali, are heightened by the effect of an enormous pressure, beds of considerable extent may be produced in this manner. Siliceous.

Iron pyrites has been observed in a deposit from the thermal springs of Chaudes Aigues in the Cantal, owing probably to the Ferruginous.

* *Edinb. Phil. Journal*, vol. ii.

decomposition of sulphate of iron by organic matter*, and ochre has been often observed forming, in the midst of travertin, small beds or veins, which owe their origin to the deposits from ferruginous waters†.

Bituminous.

To petroleum springs, which so commonly arise from the operations of volcanic fire, Mr. Lyell is disposed to attribute the bituminous shales present in geological formations of different ages.

Thus the phænomena of mineral waters afford a clew to the origin of various constituents of our globe, which it would otherwise have been difficult to explain by the mere agency of water, and relieve us from the necessity of assuming the operation of causes that have ceased to exist, in order to explain the occurrence of minerals or beds composed of silica in the midst of Neptunian formations.

Origin of springs in general.

Having now collected the principal facts of recent observation which have fallen under my notice with respect to the natural history of mineral waters, I will next proceed to state what is known with respect to their origin, and the causes of their respective peculiarities.

The notions entertained by our forefathers with respect to the formation of land springs by the infiltration of sea-water, deprived of its saltness by its passage through the intervening rocks, have long given place to the more rational theory which attributes them to the large reservoirs of rain-water, collected within the porous strata, and forced out by hydrostatic pressure, wherever a natural or artificial opening was created for them.

A German writer, however, named Keferstein‡, has attempted to cast doubts upon this explanation, and to substitute for it one founded upon certain fanciful speculations with respect to the earth's vitality, which seem to be the fitting progeny of an earlier stage of physical research.

The earth being, according to him, one great animated being, performing functions of a nature analogous to those discharged by the living creatures that exist upon its surface, the production of springs is regarded as the result of its respiration; and the discharge of steam, carbonic acid, and nitrogen, together with the absorption of oxygen, is viewed as originating in processes similar in kind, to those which are carried on by the lungs of animals.

It is not my purpose to combat this strange hypothesis, though if there be any in this country who have already become converts to it, they may perhaps find excuses for applying its

* Berthier, *Annales des Mines*, 1810. † Lecoq, *Vues, &c.* p. 120.

‡ In Kastner's *Archiv*, vol. iii. p. 359, and in his work entitled, *Deutschland geologisch dargestellt*. Halle.

principles to the case of springs, by espying difficulties in certain special instances to the application of the received theory.

It may, however, be sufficient for my purpose to remark, that, be the difficulties in question real or apparent, they are not, at least, of moment enough, or applicable to a sufficient number of cases, to induce more sober theorists to adopt the views, which it has been proposed to substitute for the received ones.

The majority of naturalists will be contented with appealing to the researches of Dr. Dalton, who, in a paper published in the *Manchester Memoirs**, has shown the adequacy of the water which descends from the heavens in the part of England he inhabits, to supply the springs of that district, notwithstanding the loss arising from evaporation.

There appears indeed, from his calculation, to be an excess of 2 inches per annum in the latter beyond the amount of rain and dew which fall; but this excess Dr. Dalton thinks may be explained without resorting to any other supposition than the one alluded to.

Yet, although the general theory will scarcely admit of dispute, it is satisfactory to collect facts on this subject, in order to compare with the former; and one singularity has been observed in the instance of springs issuing from chalk, which appear to be most copious in June, and least so in December†.

This, however, seems referable to the slowness with which water percolates so thick a stratum as the chalk, and is analogous to what has been observed with respect to terrestrial heat, where the excess of summer temperature does not reach the utmost limit of its progress into the earth till about the middle of winter.

Mr. Henwood‡ has also stated the quantity of water given out by the springs in a certain district of Cornwall, as determined by the amount raised by the engines in particular mines; and concludes, that it is greater by one third than that of the rain falling in the country.

This, however, may easily arise, owing to the mines drawing water from a much larger surface, than the area of country directly overlying them, which, as being the deepest spots for a considerable distance, they may readily be conceived to do.

To descend from the general theory of springs to the causes of their particular characters, I will first notice the circumstance of temperature. Origin of thermal springs.

* Vol. v. See also Arago on *Artesian Wells,* in the *Annuaire* for 1835, translated in *Jameson's Journal.*

† Bland in *Phil. Magazine* for 1832, p. 38.

‡ *Phil. Magazine,* New Series, vol. i., 1832, p. 287.

According to Von Buch* all springs containing carbonic acid are more or less thermal, and Gustavus Bischof goes so far as to assert, that this remark extends universally to springs of constant temperature†.

The smallest difference, he says, between the warmth of the springs of a country and that of the soil, is never less than 2¼ degrees of Fahrenheit.

But I have already observed, that Bischof generalized on too narrow a basis, when he inferred from the observations quoted in his memoir the universality of such a law.

It is one indeed directly at variance with the tenour of observations made within the tropics, which seem to show, that in warm climates the mean temperature of the atmosphere is even higher than that of the perennial springs ‡.

And if the remark be limited to colder regions, many anomalies require to be reconciled, and a much more extensive series of observations gone through, before it can be decided, whether this augmentation of temperature be the result of a general law, or of local circumstances. Thus, for example, if, as Humboldt and others have supposed, the excess of temperature in springs over the atmosphere increases with the latitude, then indeed the temperature assigned by Bischof as the minimum in the case of those near Andernach, in lat. 50¼°, squares very well with the rate of progression indicated by observations, on the springs of Paris in lat. 49°, and those of Berlin in lat. 52½° §.

For at Paris the mean temperature of the climate was found at 51°·6, and that of the springs 52°·7, the excess being 1°·1; whilst at Berlin the atmospheric temperature was 46°·4, terrestrial 50°·2, excess 3°·8, indicating a rate of progression equal to about 1°·8 of temperature to 1° of latitude.

But, on the other hand, the accurate observations of Playfair have shown, that at Edinburgh, in a still higher latitude, viz. 55°·58, the temperature of springs is identical with that of the atmosphere, so that the supposed progression would seem to be confined to a still higher latitude than this.

Neither are the observations of Wahlenberg in the Scandina-

* Poggendorff's *Annalen*, vol. xii. p. 415.

† *Edinburgh New Phil. Journal* for April 1836.

‡ See Von Buch, on the Temperature of Springs, *Edinburgh New Phil. Journal*, October, 1828, or his work on the Canary Islands, p. 84, French translation; where he accounts for the fact, from the circumstance of the springs being derived from rain, which had fallen exclusively during the colder months, and which does not readily acquire, within the slowly conducting substance of the strata containing them, the temperature of the hotter portions of the year. See also Bischof's often quoted memoir, in which he disputes the general law, and supposes the tropical springs alluded to, to have been derived from high mountains, and therefore to possess a lower temperature.

§ Humboldt on Isothermal Lines, *Edinburgh New Phil. Journal*.

vian Peninsula *, nor those of Kupffer on the Ural range †, absolutely conclusive, as to the generality of the supposed law even in the high latitudes to which they refer.

The elevation of temperature may, for ought we know, be confined to the neighbourhood of uplifted chains of mountains; it may be a consequence of those great natural events to which are owing the disturbances there experienced; and consequently it may not extend to the great plains of Russia or Siberia, where no such local influences exist. Or if it should be found on further examination to be general in northern latitudes, it will still remain to be discussed, before referring it to central heat, whether the phænomenon may not depend upon the cause suggested by Von Buch in the memoir before referred to, namely, that the transmission of temperature through the earth chiefly takes place by the infiltration of water, a cause which, of course, ceases to operate below 32°.

Granting, however, that the springs, which Bischof has noticed, owe their excess of temperature in part to a generally pervading cause of heat, we have still to account for the enormous differences in this respect existing between one and another, and this is what I now propose to consider.

The degree in which they exceed the mean of the climate is dependent, amongst other circumstances, on the elevation on the earth's surface at which they issue.

Von Buch ‡ has given various instances of springs, belonging to the same district, but bursting out at different heights, which, though they may correspond in mineral and gaseous impregnation, differ materially in temperature, the lowest being the hottest.

Boussingault§ also states, that in the littoral chain of Venezuela the temperature of the thermal springs is less in proportion as their absolute height is greater.

Thus the warm spring of Las Funcheras near Puerto Cabello, which approaches the level of the sea, possesses a temperature of 97° cent. That of Manaro, at a height of 476 metres, has only one of 64°; and that of Onoto, at 702 metres, only 44°·5.

This regularity, however, does not extend to hot springs in immediate contact with volcanos. Von Buch || conjectures, that the heat of such springs is derived from the carbonic acid which impregnates them, and which possesses itself a high temperature, as having proceeded from a great depth.

* *Annals of Philosophy*, vol. iv. 1814, translated from Gilbert's *Annalen*.

† Kupffer in *Edinburgh New Phil. Journal*, vol. xxii.

‡ Poggendorff's *Annalen*, vol. xxii. § *Annales de Chimie*, 1831.

|| Poggendorff's *Annalen*, vol. xii. p. 415.

This, however, is controverted by Bischof *, who shows clearly that no considerable augmentation could have arisen from such a cause.

Brongniart, in an article † in the *Dictionnaire des Sciences Naturelles*, has pointed out, that the temperature of thermal springs is regulated by the nature of the rocks from which they issue.

The hottest are those associated with recent volcanos, next those proceeding from extinct ones, or from primary rocks, and lowest in the scale such as are connected with younger formations; and though this rule may admit of exceptions, yet it seems to hold good in the majority of cases.

Geological position of thermal springs:

Now this observation of Brongniart will be found to harmonize, and to point the same way, with the conclusions to which I have myself been conducted by the study of thermal springs, a summary of which will be found in an article in the *London Review* for 1829, and in a memoir inserted in the *Edinburgh New Philosophical Journal* for 1831.

In these publications I have attempted to show, that by far the majority of thermal waters arise, either from rocks of a volcanic nature, from the vicinity of some uplifted chain of mountains, or lastly, from clefts and fissures caused by disruption.

In many cases, indeed, all the above circumstances are seen combined; for the same spring may at once issue from the midst of volcanic products, be situated at the foot of an uplifted chain, and proceed out of a chasm or fissure; so that, in classifying springs according to the above plan, we should find many perhaps possessing an equal claim to a place in all the three divisions.

This circumstance, however, although it might prevent our adopting the above distinction, as the basis of a classification of mineral springs, only adds strength to the argument in favour of a common origin being ascribed to them.

1st, near volcanos.

With respect to the first of these classes of springs, I have pointed out in a subsequent paper ‡, that they may be placed under two heads, namely, first, those impregnated with gases which are derived from volcanic energy, and probably owe their origin to processes now continuing; and secondly, those which, from the absence of such accompaniments, seem to be nothing more than reservoirs of water heated by coming into contact, with a mass of rock, retaining some of the warmth it had acquired from the volcanic operations of an antecedent period.

The springs of Mount Dor, of Hungary, and some of those in

* On Hot and Thermal Springs, *Ed. Journal*, 1836. † Eaux.
‡ On a Spring at Torre del Annunziata in *Edinb. New Phil. Journal*, 1835.

the Andes, are instances of the former; those of Ischia, noticed by myself, and those enumerated under the head of "*simple thermal waters*," by Anglada*, and by Fodéré†, which latter are called in the country *chaudons*, and spring from below beds of gypsum, I consider to be illustrative of the latter.

The connexion of thermal waters with uplifted chains will best be seen by coupling this description of springs with the carbonated ones which usually accompany them, and which, from the similarity of their mineral, and still more of their gaseous constitution, no less than that of their geological position, seem plainly referable to the same system of causes. 2nd, near systems of elevation.

Gustavus Bischof, in the work so often quoted, has enumerated nine of these groups existing in different parts of Europe, alike impregnated with carbonic acid and soda. These are

1. The springs of the Eyfel and Siebengebirge.
2. Those of the Westerwald and Taunus.
3. Of the Habichtswald, Meissner, Vogelsgebirge, and Rhongebirge.
4. Of the Fichtelgebirge.
5. Of the Erzgebirge.
6. Of the Bohemian Mittelgebirge.
7. Of the Riesengebirge in Silesia.
8. Of Auvergne and the Vivarais in France.
9. Of the Pyrenees‡.

Now it is to be observed, that of the above groups two, namely, the mineral springs of the Rhine Province, and those of Central France, belong to our antecedent class; and that a portion at least of the sixth group is allied to the same, since the mineral waters of Toeplitz and Bilin are manifestly in connexion with the porphyry-slate, and the volcanic products of the Mittelgebirge, and those of Franzensbad, with the little volcanic crater and scoriform lava of the Kammerburg in its immediate neighbourhood.

With regard to the remainder, it may be remarked, that the existence of trappean or porphyritic rocks in the vicinity of many of them, is a circumstance strongly corroborative of their volcanic origin, and consequently of the operation of forces capable of uplifting the mountains in their vicinity.

It is likewise a negative proof of the same connexion, that no mineral springs of such a constitution are found on the continent of Europe, considerably north of the limit to which basaltic and

* Vol. ii. p. 170.

† *Voyages aux Alpes maritimes*, p. 155.

‡ We have seen, however, that Anglada denies the existence of carbonic acid in these waters.

trappean rocks extend, a limit which nearly coincides with the line of elevation passing through the centre of Germany.

It is certain, at least, that throughout those vast tracts of comparatively level country, which constitute the greater part of Northern Russia, Poland, and Prussia, neither basaltic rocks, nor thermal or carbonated springs have been noticed, whilst both the one and the other appear to become more and more abundant, in proportion as other indications of volcanic action appear.

The above-mentioned groups however constitute but a small part of those distributed throughout Europe.

I have already shown, that the thermal springs of the Alps often contain alkali, and the occasional absence of that ingredient ought surely not to place them in another class, when their gaseous impregnation and other phænomena coincide with those included under it.

There is therefore a group of thermal springs manifesting itself, both in the central chain of the Alps, as at Baden in Argau, Schinznach, Pfeffers, and Loueche, and on its western and southern flank, at Aix in Savoy, St. Didier, Bonneval, and at Acqui and Coni in Piedmont.

Nor are other chains of mountains destitute of their own appropriate systems of thermal and carbonated springs. To mention one of the least known, that indefatigable geologist, Dr. Boué, who has lately been exploring the provinces of European Turkey, informs me, that in Servia and Bosnia, there exist acidulous and saline mineral waters, like those of Nassau, and that in the western part of the former province, as well as in Bulgaria, a line of hot springs with sulphuretted hydrogen, and probably azote, makes its appearance.

The line begins at Mehadia in the Bannat, and continues to the south of Nissa. The great masses of travertin found in the neighbourhood denote, that carbonic acid was formerly evolved in large quantities.

South of the Balkan and Orbelus, is a line of hot springs, running from east to west, which also contain sulphuretted hydrogen. Their highest temperature is 58° R. (162° Fahr.).

Eruptions of trachyte and dolerite seem to have been the precursors of the bursting out of these latter springs.

Without extending our inquiry into other parts of the globe, where it would be easy to point out groups of mineral springs similarly constituted, let us consider how the latter stand related to the mountains in the vicinity of which they lie.

Relation of these springs to the rocks contiguous.

It would seem, as I have remarked in the memoir on Thermal Waters before referred to, that a large proportion of them are placed near the line at which the elevation of the chain appears

to have commenced; but that when situated near to its axis, they generally occur in some deep valley, and consequently at a comparatively low level.

This is the case with Barege and Cauterets in the Pyrenees, and with St. Gervais in the Alps, which latter, as M. Delarive* had many years ago observed, is situated exactly on the spot which, of all others, unites most completely the conditions, of approaching in the nearest degree to the centre of the chain, and being at the same time least elevated above the level of the ocean.

But Professor Forbes, in an interesting memoir to which I have already had occasion to refer†, points out other circumstances of physical constitution, which seem to characterize the greater part, at least, of springs of this description.

He has shown, by an extensive induction of particulars, that the thermal springs of the Pyrenees, for the most part gush out from the vicinity of intrusive rocks, such as granite, serpentine, greenstone, and the like; moreover, that the structure and position of the stratum through which the latter have been thrust, are both of such a nature as to afford indications of violence.

Several of these thermal waters he has even traced, rising exactly from the line of junction between the granite and the stratified rock.

3rdly. Contiguous to extensive faults or dislocations.

And this brings me to the consideration of the third circumstance alluded to as characterizing thermal waters; I mean their connexion with faults or dislocations.

This mutual relation is illustrated by the case of the Carlsbad springs, according to the description of them given by Von Hoff‡.

They are described by him as issuing from the bottom of a narrow glen, bearing in itself the evidences of some great natural convulsion.

It lies nearly at right angles to the valleys of denudation that exist in the immediate neighbourhood; it is more narrow and more precipitous than the latter; and, as Von Hoff states, the granite which forms the fundamental rock, is overlaid by a breccia, made up of fragments of this rock cemented together by a siliceous paste, which is in great measure covered over by the calc. sinter deposited at present by the springs, but in one side of the valley protrudes itself, and appears above it.

This breccia Von Hoff attributes to the spring, which in former times, like those of Iceland, may have deposited siliceous matter; but as, on a recent visit to Carlsbad, I could perceive no kind of breccia that bore the appearance of having been cemented by the materials of a thermal water, I am disposed to doubt this

* *Bibliothèque Britannique.* † *Phil. Trans.* 1836.

‡ *Geognostiche bemerkungen über Karlsbad.* Gotha, 1825.

part of Von Hoff's statement, although able to confirm the general truth of his representation.

Stifft, in his geological description of the neighbourhood of Wiesbaden*, remarks, that the following facts have been observed by himself relative to the springs of the Nassau territory.

1st. That they follow distinctly six lines, and thus evince a determinate direction.

2nd. That the rocks in their neighbourhood manifest evident changes in the direction and inclination of their strata, especially saddle-shaped elevations, often accompanied with fractures.

3rd. That in many places the adjacent rocks themselves appear altered, and are more friable than elsewhere.

In my memoir on Thermal Springs already referred to, I have pointed out several instances of the same connexion, between the existence of evidences of dislocation in the strata, and the bursting out of thermal springs, as occurring along the line of the Pyrenean chain, as at Aleth, Rennes, and Campagne, and still more remarkably at St. Paul de Fenouilhedes, on the road from Carcassone to Perpignan, near the town of Caudiez, all in Roussillon. The same fact is still more strikingly illustrated, by the structure of the country at St. Vincent's rocks, as described by Conybeare and Buckland†, and at Matlock, as long ago pointed out by Whitehurst‡; for, since the rocks from which the thermal waters in these two instances proceed, are stratified, the inference, to which the mere inspection of the localities conducts us, is confirmed by the unconformable disposition of the strata themselves; we not only observe springs gushing out from a narrow and precipitous cleft, but we find on examination the strata tilted up and disarranged, in a manner which implies that some violent action must have taken place. Mr. Murchison and Mr. Lyell§ have also remarked, that the hot spring of Aix in Provence lies contiguous to some remarkable dislocations of the strata.

We must not, indeed, strain too far our inferences from this one circumstance; for it is probable, as has lately been shown by Mr. Hopkins‖, that natural springs, of whatever temperature, have their origin very commonly in fissures, which appear owing to dislocations or disturbances in the strata.

The latter, however, exhibit no evidences of violence, at all comparable to those afforded by the great natural chasms, to

* In Rullman's *Wiesbaden*.

† *Geological Transactions*, vol. i. New Series, "On the South West Coal Field of England."

‡ Whitehurst's *Theory of the Earth*, 1786.

§ *Edinburgh New Philosophical Journal*.

‖ *Cambridge Philosophical Transactions*, 1836.

which I have principally appealed, exhibited at Carlsbad, Matlock, and Clifton.

And it is only in the last of these instances, where, fortunately for our argument, the evidence is of a more decisive character than in the rest, that we are unable to strengthen it by other collateral proofs, derived from the presence of intrusive rocks, or the general appearance of the surrounding country.

In the other examples cited, I might have been indisposed to build upon this one fact, as a decisive proof of violent action having taken place in the locality, had not the probability of such events having occurred, obtained confirmation from other circumstances that had been pointed out.

Thus at Carlsbad, the existence of volcanic products both to the east and west of the spot, as well as the propinquity of the spring itself to a mountain range, which doubtless owes its elevation to volcanic forces, together strengthen the inference which the particular character of the locality would dispose us to adopt.

Theories of thermal springs.

It appears then, that the geological position of thermal waters in general leads to the conclusion, that they are connected with certain volcanic processes going on near the places in which they occur; but it must be at the same time admitted, that in a few special cases a high temperature is imparted to the springs of a district, by causes of a more local and superficial character.

Local causes.

Thus Kastner* states, that in the Westerwald, between Marienburg and Stockhausen, the burning of brown coal underground has caused so great a heat in the contiguous rocks, as to give rise to several warm springs, which are characterized by the presence of acetic and succinic acids, both probably derived from the slow distillation of lignite.

General causes.

Setting aside, however, these comparatively rare and special cases, let us next briefly consider, how far the facts detailed in the preceding part of this Report, will assist us in explaining the cause of that exalted temperature, which thermal springs in common with other volcanic phænomena exhibit.

With respect to this question, a recent memoir by Professor Bischof of Bonn†, may be quoted, as disposing successfully of the hypotheses, in which certain chemical processes going on at the present time near the surface, such, for example, as the decomposition of pyrites, were appealed to, as capable of producing the heat which these springs possess. He has also said enough respecting another hypothesis, that of Anglada, who attributes

* *Archiv*, vol. xvi. † *Edinburgh New Philosophical Journal*, April, 1836.

the heat of springs to the action of electricity. This mighty agent is doubtless concerned in many of the changes which go on in rocks, but before we attribute to it the production of that steady heat which resides in certain springs, we ought to consider, what peculiar disposition of strata would be necessary to give rise to it, what evidence there is of such a disposition existing, and why, if it exist at all, it be not more general, and thus render the occurrence of hot springs less a local phænomenon.

None of these questions having been entered upon by Anglada, it would be superfluous at present to proceed to a formal consideration of his hypothesis.

Neither need I dwell upon any such hypotheses, as are founded on assumptions, which either seem contrary to acknowledged principles of physics, or which would be rejected by the general voice of men of science as absurd and fanciful.

Thus I shall do no more than allude to the mode, in which Aristotle somewhere accounts for the high temperature of springs, by supposing, that as the figure of the earth is spherical, the solar rays penetrating its substance, ought to meet in the centre, as in the focus of a burning glass, and thus produce there an intense degree of heat.

Neither shall I labour to refute the idea of Keferstein, that thermal springs are merely the result of, what he is pleased to call, the respiratory process of the earth, resting, as that opinion does, upon the assumption, that the globe itself is an animated body, a position, which I am loth seriously to attack, not knowing in what precise sense his language is to be interpreted.

But there remain two theories with respect to the origin of thermal springs, that seem to deserve a more attentive consideration.

Chemical theory stated.

The former of these supposes them to arise from chemical processes carried on within the earth, processes, however, which possess nothing, in common with those witnessed on or near the surface, except the circumstance of being attended with an absorption of oxygen.

If it be further demanded of the advocates of this theory, what particular chemical processes are alluded to, they will probably reply*, that a competent explanation of the phænomena

* They ought however carefully to distinguish, between that which appears to be a direct inference from observed facts, and what at the most can advance no higher claim, than of being a plausible conjecture. The general occurrence of volcanos in the neighbourhood of the sea, and the constant disengagement of aqueous vapour and of sea-salt from their interior, are facts, which establish in my mind a conviction, that water finds its way to the seat of the igneous operations, almost as complete, as if I were myself an

would be afforded, by the supposed oxidation of the bases, of those alkalis, earths, and metallic oxides, which are found to constitute the crust of the globe, through the agency, first of water, and afterwards of atmospheric air.

Such, in a few words, was the theory which I adopted, to account for the phænomena of volcanos* in a work published on that subject in 1826†; and to the same, after a mature, and, I trust, an impartial review of the question, I am still disposed to adhere, in preference at least to any other.

In an article entitled Geology, in the *Encyclopædia Metropolitana*, I have endeavoured to reply to all the arguments that had been subsequently urged against my views; and if I have not noticed every individual objection, it has only been, because the same difficulties were brought forward again and again by different persons, often without any allusion being made to the answers, which I had given to similar ones before.

Theory of central heat.

The latter theory, discarding all chemical operations whatsoever, regards thermal springs as arising merely from the internal heat of the globe, and consequently as possessing a temperature high, in proportion to the depth from which they have themselves proceeded.

For, as the temperature of the earth augments, as we descend, on the average, about 1° of Fahr. for every 100 feet, it is evident, that, if the increase be progressive, water would arrive at its boiling point at a depth not exceeding three miles, and there is no difficulty in understanding, that it should retain the greater part of that exalted temperature, when once the channels and passages in the rock, through which it reached the surface, were thoroughly penetrated by the heat.

The theory just mentioned is sanctioned by the high autho-

eye-witness of another Phlegethon discharging itself into the bowels of the earth, in every volcanic district, as in the solitary case of Cephalonia.

Nor, as I shall afterwards attempt to prove, is the access of atmospheric air to volcanos more questionable, than that of water; so that the appearance, of hydrogen united with sulphur, and of nitrogen, either alone, or combined with hydrogen, at the mouth of the volcano, seems a *direct* proof, that oxygen has been abstracted by some process or other from both.

Having satisfied our minds with regard to the *fact* of internal oxidation, we naturally turn to consider, what principles can have existed in the interior of the earth, capable of abstracting oxygen from water, as well as from air; and this leads us to speculate on the bases of the earths and alkalis as having caused it. But in ascribing the phænomena to the oxidation of these bodies, we ought not to lose sight of the Baconian maxim, that in every well-established theory, the cause assigned should be, not only competent to explain the phænomena, but also known to have a real existence, which latter cannot be predicated of my alkaline and earthy metalloids in the interior of the earth.

* *Description of Active and Extinct Volcanos.* London, 1826.

rity of Laplace, and has also received the support of many modern naturalists.

Professor Bischof*, in adopting it, has undertaken in a late paper first of all to refute the opposite hypothesis, but in attempting so to do, has, I conceive, mistaken the views of its advocates.

Thus he quotes an experiment of his own, in which the combustion of 15 grains of sodium, in water containing a quantity of sulphuric and muriatic acid, such as would be adequate to form the saline matter present in a particular thermal spring, raised the temperature of 1000 grains of water scarcely 3°; and this he alleges as a proof, that the heat cannot have arisen from any process of oxidation in which sodium acts a part.

But under either view of the subject, the increased temperature of the spring must be attributed to that of the contiguous rocks, the only question being, do these rocks derive their high temperature from a central fluid mass, or from chemical processes taking place generally in the interior of the globe?

Having discussed this question at length elsewhere, I will at present confine myself to remarking, that the supporters of Bischof's views ought to be able to explain to us, why thermal springs are of local occurrence, and most frequent in proportion to the frequency of other indications of igneous activity; and if these latter indications are assumed to be themselves nothing more, than the result of the contraction of the earth's crust upon its internal fluid contents, why that contraction should be always accompanied with those exertions of explosive energy which we witness in volcanos, and those emissions of gas which are common to both.

They should also explain to us, why primary rocks, traversed as they so frequently are with fissures of all descriptions, should not in every part of the world, and in every kind of situation, give rise to hot springs, by evolving steam from their interior, and why they never appear to give issue to that class of thermal waters, which I have noticed in Ischia as being unaccompanied with gaseous products, and which therefore I suppose, to be purely the result of the infiltration of water to spots in the interior of the earth retaining a high temperature.

In order however duly to appreciate the degree of support, which the chemical theory of thermal waters appears to derive from the nature of the gases which accompany them, I shall next propose to consider in detail the manner, in which these elastic fluids may severally be supposed to have been generated.

* *Edinburgh Phil. Journal* for April 1836.

The carbonic acid, which is so frequent an accompaniment of thermal waters, is explained by Bischof *, as deriving its origin from the calcination of earthy carbonates by the heat beneath; and to this view there seems to be no objection, provided only we admit, that a portion of water is present, without which, as Faraday has shown, no disengagement of carbonic acid would take place under the influence of even a great heat.

Origin of the carbonic acid evolved from springs.

But that the amount of carbonic acid emitted bears some relation to the igneous or eruptive agency heretofore exerted, will appear by a mere enumeration of the localities in which this gas most abounds.

Passing over its copious emission in the neighbourhood of active and extinct volcanos, I may notice the observations of Hoffman †, who has stated, that the carbonic acid so abundantly evolved at Pyrmont, rises out of what he describes as a circular valley of elevation, caused by the heaving up of the rocks in all directions round this central point.

Sometimes also the evolution of carbonic acid is connected with faults, as has been observed by Professor Phillips with respect to the carbonated or petrifying springs of Yorkshire ‡.

So general indeed is the distribution of calcareous rocks in the older, as well as the more modern formations, that I do not see the force of the objection started by Berzelius to the chemical theory of volcanos, in a notice with which he some years ago honoured the work I had published on that subject §, in which he says, that it fails in accounting for the extrication of carbonic acid gas, as a consequence of volcanic action.

For my own part, inasmuch as an intense degree of heat is the immediate effect of these operations, and as rocks containing carbonic acid in a fixed state are so generally diffused, I should conceive that the extrication of this gas would have been anticipated to be a natural result of the process; unless, indeed, by those theorists, who, maintaining the contrary hypothesis in its simplest form, refuse even to admit that water has had any necessary share in the phænomena.

The evolution of nitrogen from springs has been discussed by Berzelius, Anglada, and others.

Origin of the nitrogen.

Berzelius ‖ supposes it to arise from the decomposition of the organic matter which these waters contain, whilst Anglada ¶

* *Vulkanischen Mineralquellen*, p. 255.

† On Valleys of Elevation, *Edinburgh New Phil. Journal*, October, 1830.

‡ See my memoir on Thermal Springs already referred to.

§ *Jahresbericht*, vol. vii. p. 352.

‖ "Analyse des Eaux de Carlsbad," *Ann. de Chim.*, vol. xxiii.

¶ *Mémoires pour servir, &c.*

refers it to the atmospheric air present in them, the oxygen of which is absorbed by the sulphur found along with it.

The theory of Berzelius may perhaps suit those cases, in which the quantity disengaged is small, but can scarcely be extended to others, in which it is more considerable.

No amount of organic matter, that can be supposed to exist in the thermal water, could produce a constant supply of nitrogen, continuing for hundreds and probably thousands of years, equal on an average to 222 cubic feet in the 24 hours, as at the hot spring of Bath.

It would also have seemed needless to remark, had not the circumstance been overlooked by some who have commented upon this phænomenon, that the decomposition of organic matter would generate other gases never met with amongst thermal springs, especially carburetted hydrogen, which is actually found to accompany nitrogen in cases where the latter proceeds from organic matter, as was determined, with respect to the gas that renders buoyant the floating island of Derwentwater, by Dr. Dalton.

The explanation of Anglada seems to me only faulty in not being sufficiently general.

Sulphur no doubt is one of the principles by which the oxygen is abstracted, but it does not seem probable that it should be the only one; and the case of Bath alone serves to show, that it is sometimes absent altogether from waters, where the evolution of nitrogen is most abundant.

In short, the only direct inference, that seems deducible from the fact of the copious evolution of nitrogen from thermal waters is, that certain processes, occasioning the abstraction of oxygen from common air, are going on in the interior of the earth.

This inference remains the same, whether we suppose the nitrogen emitted, to consist merely of that carried down by the atmospheric waters, by which the thermal spring is maintained, or to be the residue of the atmospheric air, that had found its way into cavities, where these processes are taking place.

Both explanations may occasionally be true; but whichever one we choose to adopt, the ultimate fact is still as before, namely, that a quantity of air, which, if derived from the atmosphere, contained originally $\frac{1}{5}$th of its volume of oxygen, and if from atmospheric water, would contain nearly double that amount, returns to the surface, often with scarcely $\frac{1}{100}$th, and at most with not more than $\frac{1}{10}$th, of this latter ingredient.

That atmospheric air does find its way into the interior of the

globe, and probably pervades every portion of its solid contents, is a fact, of which a little reflection will convince us.

Independently of, the cracks and fissures, by which the earth's crust is everywhere intersected, the large cavities it so frequently envelopes, and its general porosity and permeability to water containing air in solution, the solid strata themselves have the property, as has been shown by Saussure*, in various degrees, of absorbing oxygen and nitrogen gases; though it is to be remarked, that by a curious provision of nature, apparently designed to forward the process of internal oxidation, the two gases are absorbed, not in the proportion of five to one, but in nearly equal ratios.

Professor Meinecke of Halle† is the only person, so far as I know, who has availed himself of this, as a principle on which to explain other phænomena; and his remarks, owing to certain loose and fanciful speculations interwoven with them, have not yet obtained much attention.

Nevertheless, if it be true, that air pervades even the solid portions of our globe, down at least to a considerable depth, it seems not absurd to imagine, that it may suddenly be augmented by an increase of atmospheric pressure above, or diminished by processes taking place in the interior of the earth.

Such, in the main, are the views of Professor Meinecke, who imagines the amount of air retained in the interior of the earth, to be in a state of constant oscillation, and thus, reacting upon the atmosphere above, to be one of the causes of the variation of the barometer. He even attributes, to an extraordinary absorption of air within the earth, a remarkable sinking of the barometer, which took place without any other assignable cause at Christmas 1821.

Origin of the sulphuretted hydrogen.

The sulphuretted hydrogen, which so many springs contain, has been attributed to the action of organic matter upon alkaline and earthy sulphates; and M. Henry of Paris‡ has cited an example, where a spring, which at its source contained sulphates of soda, magnesia, and lime, but no sulphuretted hydrogen, was found to have acquired a trace of that gas, at the expense of its sulphuric acid, after mixing with the water of a washing place.

It seems probable, that the hepatic smells, which occur in the waste and stagnant waters of towns, sometimes arise from this

* *Bibliothèque Britannique,* vol. xlix. p. 319.
† Schweigger's *Journal,* vol. viii. 1823.
‡ *Journal de Pharmacie* for 1827, p. 493.

cause; and M. Brongniart* attributes the sulphuretted hydrogen present in the mineral water of Enghien, to the action of organic matter upon beds of gypsum belonging to the Paris Basin.

But no one would attempt to explain in this manner, the sulphuretted hydrogen contained in many thermal waters, still less that evolved from volcanos; a phænomenon, which seems to me to supply just the same evidence of the decomposition of water within the earth, which the emission of nitrogen affords of the abstraction of oxygen from atmospheric air. And if it should be established, as many observers of volcanic phænomena have thought probable, that the sulphur, which finds its way to the surface by the agency of volcanos, is always held in solution either by oxygen or hydrogen gases, the enormous quantity of either principle which is sent back to the atmosphere in conjunction with this Inflammable, may be in some measure appreciated from one circumstance alone, namely, from the vast beds of volcanic sulphur accumulated in many parts of Italy, and still more remarkably in Sicily.

Professor Phillips is even of opinion, that the origin of the mineral impregnation of the waters of Harrogate is to be ascribed, to the chemical effects specially exerted along the line of a subterranean disturbance, which he has traced in the vicinity of these springs; and Mr. Murchison has been led to similar conclusions, with respect to the sulphureous spring of Llanwrtyd, by the geological structure of that locality.

Origin of salt springs.

The only remaining class of springs, that requires further notice, is that which contains common salt, and the other ingredients of our present seas.

The origin of these springs from masses of salt or muriatiferous clays, produced by the evaporation of sea-water, or of lakes of similar composition, would seem sufficiently obvious; and Mr. Lyell† has even attempted to explain the manner, in which a deposition of salt may be taking place at the present day from the waters of the Mediterranean, so as eventually to build up a bed of rock salt underneath it.

But although the law of the increasing specific gravity‡ of water, in proportion to the degree of its saline impregnation, would favour the process of deposition, when once it had commenced, by keeping up a constant supply of the strongest brine near the bottom of the sea, we still seem to want some agent, for

* *Dict. d'Hist. Nat.*, art. EAUX. † *Principles of Geology*, vol. i. p. 297.

‡ See a curious paper on the increasing strength of a brine well in proportion to its depth, in the *Phil. Magazine*, vol. iv. p. 91.

bringing about a separation of its solid contents, from a fluid so far removed from saturation, as the water of our present seas is found to be.

Now a submarine volcano, or any other independent cause, producing a high temperature in any part of the bed of the ocean, might supply this desideratum; it would separate the salt from that portion of the water which came most within its immediate influence, converting the fluid into vapour, which, in a highly compressed condition, we may imagine to be interposed between the bed of salt in the act of forming, and the body of the superincumbent ocean.

That volcanic action may have had some share in the formation of beds of salt, is no new idea, and is immediately suggested by the almost constant association, of sulphuric salts, and especially of gypsum, with the former.

Thus Von Buch*, remarking on the connexion of rock-salt and brine springs with anhydrous gypsum at Bex in Switzerland, attributes them both to direct sublimation from the interior of the earth, the common salt being accompanied by sulphuretted hydrogen, which, by its gradual conversion into sulphuric acid, had given rise to the formation of sulphate of lime.

That rock-salt is sometimes sublimed from the bowels of the earth we know by an examination of volcanos; and where common salt is found abundantly in thermal springs which are of volcanic origin, and issue from primary rocks, as is the case with that of St. Nectaire in Auvergne, and possibly that of Wiesbaden in Nassau, it seems but reasonable to attribute its occurrence to a similar cause.

Proust† even has stated, that the salt mine of Burgos in Spain lies in the crater of an extinct volcano; and though he may possibly be mistaken as to this exact point, still such a notion would hardly have arisen, had not the beds been in a manner surrounded by volcanic products.

Without, however, proposing so bold an hypothesis as that of sublimation, to account for the production of salt beds in general, we may perhaps see reason to suppose, that volcanic heat has in many cases caused their deposition, and that the sulphates which accompany them have arisen from the sulphuretted hydrogen, which is at the present day an ordinary effect of volcanic processes.

In my memoir on the Lake Amsanctus‡, I have attempted to trace the connexion, between the operations of volcanos, the

* Poggendorff's *Annalen*, 1835. † *Journal de Physique*.

‡ Published by the Ashmolean Society, Oxford 1836.

emanations of carbonic acid, and the formation of beds of rock-salt; on the present occasion it may be sufficient to quote the following brief summary of the points therein insisted on.

Volcanos give out	Sulphuretted hydrogen, sal ammoniac, boracic acid, muriatic acid, steam;
And cause	Deposits of sulphur, of sulphuric salts, of muriatic salts, &c.
Moffettes, connected geographically with volcanos now in action or extinct, give out	The same principles;
And cause	Deposits of sulphur and of sulphuric salts.
Many tertiary clays, some of which are connected in a geographical sense with volcanos	Contain beds of sulphur, of earthy sulphates, and of common salt.
Most salt formations are associated with	Beds of gypsum.
Some with	Sulphur.
Others with	Sal ammoniac.

Works on mineral waters.

I shall now conclude, by enumerating a few of the newer works on mineral and thermal waters that appear to afford the most original and important information on the subject, considered in a scientific point of view.

On English medicinal springs, Dr. Scudamore* has published a good practical treatise, and with the assistance of Mr. Garden, has undertaken to give an analysis of the more important ones which this country possesses. His work, however, is more adapted for practical physicians than for men of science, as he has limited himself exclusively to those mineral waters which already possess a reputation as medicinal agents.

Professor Anglada† of Montpellier has published a very detailed and elaborate description of the thermal springs of the Eastern Pyrenees, in which he has investigated in particular, the

* *Treatise on the Composition and Medical Properties of the Mineral Waters of Buxton*, &c. Second Edition. London, 1833.

† *Mémoires pour servir à l'Histoire générale des Eaux minérales sulfureuses*, 2 vols. 1827; and *Traité des Eaux minérales des Pyrénées Orientales*, 2 vols. 1833.

condition in which the sulphureous principle of these waters exists, and that peculiar organic matter which is associated with the waters.

Having already commented upon these points, I need only further remark, that I consider the work in general a most valuable addition to our knowledge.

M. Longchamp, who was expressly engaged by the late French Government to examine the mineral waters of that country, has completed his report on those of Vichy*, which appears to be drawn up with considerable care, but has been arrested in the further prosecution of the design by the overthrow of the Bourbon dynasty. In a little work, entitled "*Annuaire des Eaux Minérales*" for 1831, he has given a sketch of the principal springs of the Pyrenees and of others in France, which may be consulted to advantage.

The work of Alibert†, though it bears the name of a distinguished medical writer, is evidently designed as a popular compendium, and therefore hardly comes under review on the present occasion; nor am I aware of any other work of scientific interest on this subject, that has recently appeared in the French language.

In Germany works on mineral waters abound; but perhaps the most important is one published by Professor Bischof ‡ of Bonn in 1826, relative to the mineral springs of the Rhine province and others of similar constitution, replete with valuable information, and important general views.

In criticising some of the latter, I have all along been conscious of the risk I incurred of being myself in error; nor should I, perhaps, have been tempted to question them, had it not appeared to me, that inferences deduced from one particular class of mineral waters, ought to undergo the test of a severe scrutiny, before we permitted ourselves to apply them to the springs of other and distant regions.

Brandes §, with the assistance of Kruger, has published a very elaborate account of the waters of Pyrmont, and more recently a still larger work on those of Meinberg ||, containing, not only a detailed description of the spring, but also of the topography, antiquities, and natural history of the neighbourhood.

But it would be endless to enumerate the various works on particular mineral waters, which have issued from the German

* *Analyse des Eaux Minérales de Vichy*, 1825.

† *Précis Historique sur les Eaux Minérales*. 1826.

‡ *Die Vulkanischen Mineralquellen Deutschlands und Frankreichs*. Bonn, 1826.

§ *Beschreibung der Mineralquellen zu Pyrmont*. 1826.

|| *Mineralquellen zu Meinberg*. Lemgo, 1832.

press, and to which this general character seems to apply, that, although more frequently replete with mystical and absurd hypotheses, than works of the same class in England, they display in general greater research and a richer fund of scientific information.

Of general works, I may mention that of Scherer* on the mineral waters of the Russian empire, which testify to this important fact, that there are neither thermal nor acidulated springs in any part of that vast tract, till we approach the mountains of the Caucasus and Oural, or the volcanos of Kamschatka.

Professor Schuster† of the University of Pesth has lately edited the elaborate work of Kitaibel on the Mineral Waters of Hungary, which will be found to contain a very detailed, and probably authentic, account of their properties.

But to the general reader the necessity of consulting these local authorities will soon be superseded, by the appearance of the treatise of Dr. Osann of Berlin‡, of which the two first volumes have been already published.

The first of these includes, a very complete sketch of the general views, entertained, with respect to the nature and constitution of mineral and thermal springs, and a *catalogue raisonné* of those best known, classified under their respective heads.

The second volume is occupied by a detailed description, of those of Germany, and some other contiguous countries, with copious references to original sources of information.

The whole appears to be compiled with great care and research, and promises, when finished, to be the most complete work extant on the subject.

Since the appearance of the first volume of Dr. Osann's work, Dr. Gairdner of Edinburgh has brought out a very compact, and useful Manual, in the English language, on the same subject§. A large portion of its contents indeed are evidently extracted from Osann; nor does it appear, that the author has drawn much from any stores of his own in the facts stated by him.

Nevertheless the multitude of details brought together, and judiciously arranged in this little volume, ought to secure it a place in every scientific library; and the best proof I can fur-

* *Versuch der Heilquellen des Russischen Reichs.* St. Petersburg, 1820.

† *Pauli Kitaibel Hydrographica Hungariæ,* edidit J. Schuster, Pesth, 1829.

‡ *Darstellung der bekannten Heilquellen Europa's.* Berlin, vol. i. 1829, vol. ii. 1832.

§ *Essay on the Natural History, &c. of Mineral and Thermal Springs.* Edinburgh, 1832.

nish of my own opinion of its merits is, that I conceived it to have superseded the demand for a distinct work on the subject, which I had for several previous years been preparing.

Indeed I have been induced in some measure to modify the nature of this Report in consequence, having endeavoured to be most full on those points, which had been passed over by Dr. Gairdner, and in other instances supplying rather a comment upon the facts he had collected, than a mere recapitulation of their substance.

Appendix to Page 42.

When mentioning the reported presence of oxygen in thermal waters, I ought to have added, that Fodéré, *Voyages aux Alpes maritimes*, states, that this gas was extracted, by boiling, from the water of Roccabigliera in Piedmont, in such quantities, and of such purity, as led him to believe, that a portion of deutoxide of hydrogen must have been present to occasion it. But so extraordinary a fact in the history of thermal waters, as this would be, requires further confirmation.

Catalogue of

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours† o[f]	
						Water.	Gas.
British Islands. N. Lat. 55° to 51°. W. Long. 1 to 5°. Mean temp. reckoned about 49°.*	Bath	New red sandstone	Somersetshire	0	King's Bath 66°	King's Bath 28,339	King's Bath 222
	Bristol	Carboniferous limestone in a valley of disruption	Gloucestersh.	0	Hot Well 25	....	....
	Buxton	Ditto	Derbyshire	4	St. Anne's 33	St. Anne's 13,500	St. Anne' 41,60
	Bakewell	Ditto	Ditto	3	Bath Spring 13	....	....
	Stony Middleton	Ditto	Ditto	4	——— 14	....	....
	Taafe's Well	Coal strata	Near Cardiff, S. Wales	0	——— 21	....	18·0
	Mallow	Carboniferous limestone	County of Cork, Ireland	0	Spa Well 23	....	....
Germany. N. Lat. 51° to 49°. W. Long. 24° to 32°. Mean. temp. reckoned about 50°.	Bertrich	Connected with extinct volcanos	Near Treves, Eyfel	4	40	7240	....
	Aix la Chapelle	At the junction of clay slate, and carboniferous limestone	Lower Rhine Province	4	Kaiserquelle 85.5	....	....
	Borset	Ditto	Ditto	4	Mühlenbend 121·5	....	....
	Ems	Clay slate	Nassau	3	Rondeel 81	12,400	....
	Wiesbaden	Chlorite slate	Ditto	3	Kochbrunnen 108	84,092	....
	Schlangenbad	Clay slate	Ditto	4	Schachtbrunnen 27	21,328	....
	Soden	Ditto	Near Frankfort on the Main	3	Gemeindebrunnen 20	....	....
	Kreutznach	Felspar porphyry	Lower Rhine Province	3	Münster am Stein 36	....	....

* N.B. In this estimate of mean temperature, no allowance is made for height. It is evident, therefore, Buxton, Bakewell, &c.

† Where the name of the spring is not given, the number is understood to indicate the amount evolved

‡ N.B. Where not otherwise specified, the spring alluded to in this and the next column is assumed to

Thermal Springs.

ases evolved & their relative roportions one to the other.				Gaseous contents.	Solid contents.		
acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated‡.	Nature of the more abundant and of the more active ingredients present.	According to
				C.In.	Grs.		
to 3.	3·5	96·5	Daubeny ...	Carbonic acid 1·2	King's Bath 15	Mur. lime and magnesia; *iron*, (*Iodine*, *Cuff.*)	Phillips.
0.	8	92.	Ditto	Carbonic acid 3·750 Common air 0·375	Hot Well 5·95	Sulph. soda, mur. of lime .	Carrick.
0.	0	100.	Pearson ...	Carbonic acid 0·187 Azote 0·580	St. Anne's 1·875	Mur. magn. and of soda ...	Scudamore.
0.	0	100.	Daubeny ...	....	Bath Spring 3·5	Sulph. of lime, mur. of soda	Daubeny.
0.	0	100.	Ditto	....	Warm Spring 2·0	Sulph. of soda and mag., mur. lime	Ditto.
0.	3·5	96·5	Ditto	....	——— 1·2	Sulphate of magnesia	Ditto.
0.	6·5	93·5	Ditto	....	Spa Well 0·3	Carbonate of lime	Ditto.
....	.....	......	....	Carb. acid, with a trace of sulph. hyd.	18·267	Carb. and sulph. of soda; *Lithia, potass*	Funke.
30.	.....	69·5	Monheim...	Sulphuretted hydrogen	Kaiserquelle 31·95	Mur., carb., and sulph., soda; *Sulphuret of sodium, phosph. soda*	Monheim.
18.	2	80.	Daubeny ...	Carbonic acid 7·6 Nitrogen 19·0	Muhlenbend 34·0	Mur., carb., and sulph., of soda; *Lithia, strontian, fluoric acid*	Ditto.
0.	0	0	Ditto	Carbonic acid	Kesselbrunnen 28·9	Carb., mur., and sulph., soda; *Strontian, barytes, phosph.* and *fluoric acids.*	Kastner and Struve.
73.	0	27.	Ditto	Ditto	Kochbrunnen 57·59	Mur. of soda, lime, and potass; *Bromine, manganese,* and *fluoric acid*	Ditto.
....	.....	......	....	Carbonic acid with a little nitrogen	Schachtbrunn 6·0	Carb. of soda, muriate of soda	Fenner.
....	.....	......	....	Carbonic acid	Saltzquelle unter der Brucke 119·8	Mur. of soda; *Potass, bromine*	Schweinberg.
....	.....	......	....	....	Theodorshall 87·9	Mur. of soda, lime, and magnesia; *Potass, alumine, phosphoric acid*	Prieger.

that a deduction must be made in all cases where the spring is placed above the level of the sea, as at

from all the thermal springs belonging to the locality.
be the same, as that of which the composition is given.

Catalogue of Thermal

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours of Water.	Gas.
Germany. N. Lat. 51° to 49°. W. Long. 24° to 32°. Mean temperature estimated at about 50°.	Wolkenstein ...	Mica slate	Saxony.........	13	33·5	....	....
	Wiesenbad	Ditto	Ditto	13	20·0	....	....
	Carlsbad	Granite, in a valley of disruption	Bohemia	11	Sprudel 117·0	Sprudel 111,715	....
	Bilin..............	Gneiss	Ditto	6	16·0	12,288	....
	Töplitz............	Volcanic porphyry	Ditto	6	Hauptquelle 71·0	77,250	....
	Warmbrunn......	At the foot of a granitic chain	Silesia	10	Trinkquelle 47.	....	....
	Landeck	Gneiss	Ditto	14	Old Bath 35·5	12,960	....
*Germany.** N. Lat. 48° to 46°. W. Long. 26° to 30°. Mean temp. estimated at about 51°.	Wildbad	Granite	Wirtemburg...	13	Hauptquelle 47	....	....
	Baden-baden ...	Ditto	Duchy of Baden	4	Ditto 96·4 F.†	12,033	....
	Baden-weiler ...	Ditto	Ditto	......	30·5	....	....
	Baden	Jura limestone............	Austria	6	68·5	Hauptquelle 40,950	....
	Gastein............	Granite	Saltzburg Alps	30	66·5	4 principal springs 100,080	....

* This, however, is far above the mark with reference to the majority of springs enumerated, in consequence

† Within the same range of latitude as the above occur the following thermal springs, few of which as stated below, viz.

In Moravia.	°
Uttersdorff	37·25
Töplitz	12·00

In Styria.	°
Doppelbad, near Gratz	32·75 F.
Romerbad, near Cilli ...	48·00
Neuhaus, near Cilli......	46·25

In Carinthia.	°
Töplitza	46·50
Montfalcone, near Trieste.	50·00
In the Tyrol.	
On the Brenner	23·0

‡ Professor Forbes, *Philosophical Transactions*, part ii., 1836.

Springs. (Continued.)

...ses evolved and their relative proportions one to the other.				Gaseous contents.	Solid contents.		
...acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
				C.In.	Grs.		
1	2	98	Daubeny ...	Carbonic acid	1·845	Carbonate of soda	Kuhn.
[illegible]	2	98	Ditto	Ditto	4·03	Carb., sulph., and mur., of soda	Lampadius.
...	......	......	....	Ditto 11·85	49·6	Sulph. and carb. of soda; *Strontian, manganese, fluoric* and *phosph. acids*	Berzelius.
...	......	......	....	Ditto 33·58	39·2	Carb., sulph., and muriate of soda; *Lithia, potass,* and *manganese, phosph. acid*	Steinmann.
...	......	......	....	Ditto 2·4	15·6	Carb. and sulph. of soda; *Phosph. acid* (Berzelius)	Ambrozzi.
[illegible]	5·3	94·7	Daubeny ...	Nitrogen 0·735 Sulph. hyd. 6.6 to 8.0	4·77	Sulph. and carb. of soda; *Carb. of ammonia*	Tschortner.
[illegible]	0	100	Ditto	Carbonic acid 1·00 Sulph. hyd. 4·33	2·62	Sulph., and mur., of soda.	
[illegible]0	6·44	91·56	Weiss	Carbonic acid 12·00 Nitrogen 79·25 Oxygen 8·25	3·59	Mur., carb., and sulph., of soda	Sigwort and Weiss.
...	......	......	....	Carbonic acid	26·331	Mur. of soda, and of lime, sulph. of lime, silica	Otto and Wolf.
...	......	......	....	Ditto	1·7	Chiefly carb. of lime	Schmidt.
...	......	......	....	Sulph. hyd. 3·33 Carbonic acid 1·77	1·076	Sulph., lime and magnesia	Schenk.
...	......	......	....	Carbonic acid	2·7182	Sulph. of soda, mur. of soda, and potass	Hünefeld.

...f their high elevation.

...ave been sufficiently examined, but which exceed the assumed mean temperature (51°) of the climate,

In Croatia.	°	*In Hungary.*	°	*In Hungary.*	°
...lika	82·25	Ofen, or Bada	93·5	Szalathny	9·8
...pina	62·	Trencsin	53·0	Lucska	26·0
...linczha	53·	Pöstheny, near Presburg...	95·75	Glasshütte, near Schumnitz	53·0
...ker	73·25	Ribar, near Neusohl	27·80	Eisenbach, near ditto	53·0
...oicza	21·25	Altsohl, near ditto	32·75	Parad, near Erlau............	35·0
		Stuben, near Kremnitz ...	59·75	Szobranez, near Unghoar .	19·25
		Gran	13·9	Budos, near Fünfkirchen...	86·75

Catalogue of Thermal

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours o Water.	Gas.
France. From Lat. 51° to 47°. Long. 1° to 5°. Assumed mean temp. 51° Fahr.	St. Amand	Slate covering the coal formation	Near Valenciennes, Dep. du Nord	......	28°	....	....
	Bourbonne les Bains	Granite, covered by Jura limestone	Connected with the chain of the Vosges: Nr. Chaumont, Dep. Haute Marne	......	La Fontaine 80	2 springs 2,916	....
	Luxeuil	Granite, covered with sandstone	Near Veseul, Dep. de Haute Saone	......	Grand Bain 75·5	8,640	....
	Plombieres	Granite	Near Epinal, Dep. de Vosges	13	Ditto 95·75	9,000	....
	Bains	Ditto	Near ditto, ditto	......	Grosse Source 71	....	....
	Bagnoles	Ditto	Near Alençon, Dep. d'Orne	......	28	....	....
France. From Lat. 47° to 44°. Long. 0° to 4°. Assumed mean temp. 56° Fahr.	Bourbonne l'Archambault	Slate formation	Connected with the volcanic chain of Central France: Near Moulins, Dep. l'Allier	......	Grand Puits 69	Grand Puits 86,400	....
	Bourbon Lancy ..	Ditto	Near ditto, ditto	......	Ecures 84	10,800	....
	Vichy	Coal formation, covering granite	Near Gannat, Dep. de l'Allier	......	Bassin des Bains 57	9,360	....
	Neris	Sandstone and coal, resting on granite	Nr. Montluçon, Dep. de l'Allier	......	Puits de Cesar 89·5	19,800	....
	Mont Dor.........	Trachyte	Near Clermont, Dep. de Puy de Dôme	34	Bains de Cesar 52 F.	12,780	Bains d Cesar 4,2
	Bourboule	Ditto	Ditto	28	65 F.	....	....
	St. Nectaire......	Ditto	Ditto	......	Gros Bouillon 45·75	....	....
	Chaudes Aigues.	Gneiss	Nr. Aurillac, Dep. de Cantal	......	Par 118·0	307,188	No. 1 2 3

* The mark (*) indicates that the gas

Springs. (Continued.)

...ases evolved and their relative ...roportions one to the other.				Gaseous contents.	Solid contents.		
... acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
					Grs.		
...	......	......	......	Sulphuretted hyd. ...	......	Sulphuret of sodium, sulphate of soda, and magnesia	
0	0	100	Longchamp.	......	52	Muriates of soda and lime, sulphates of lime and magnesia	Athenas.
8	4·5	77·49	Athenas				
...	......	......	......	......	......	Muriates and sulphs. of soda, lime, and magnesia	
...	......	......	......	......	......	Muriates and sulphs. of soda, magnesia, and lime	Vauquelin.
...	......	......	......	......	......	Muriates of soda, lime, and magnesia.	
*	......	*	Longchamp.	......	......	Muriates of soda, magnesia, and lime.	
*	......	*	Longchamp.	Carbonic acid	......	Mur. soda, sulph. soda.	
...	......	......	......	Ditto	13·478	Mur. of soda and potass, sulph. soda and lime	Puvis.
0	0	0	Longchamp.	Ditto	Source des Celestins 62.	Carb., mur., and sulph. of soda	Longchamp.
...	......	100	Ditto	......	......	Carb., mur., and sulph. of soda.	
)·0	0·85	9·85	Daubeny ...	Carbonic acid	Source de la Madelaine 11·4	Carb., mur., and sulph. of soda	Bertrand.
...	......	......	......	Ditto	Source des Fièvres 18·2	Muriate of soda.	
...	......	......	......	Ditto	2nd Spring 50·0	Carb., sulph., and mur. of soda	Bouillay and Henry.
7	13	30	Daubeny ...	......	Source de Par 14·5	Carb. and mur. of soda, magnesia, lime, and oxide of iron.	Chevallier.
0	15	25					
7	1	12					

...exists, but that its proportion is unknown.

Catalogue of Thermal

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours o[f] Water.	Gas.
France. From Lat. 47° to 44°. Long. 0° to 4°. Mean temp. 56° Fahr.	Chateau-neuf ...	Volcanic rocks	Con. with volc. chain of Central France: Near Gannat, Dep. de Puy de Dôme	......	Grand Bains 45°·75	....	....
	Evaux	Granite	Near Neris, Dep. de Creuse	......	Puits de Cesar 81·75	....	....
	Saint Laurent ...	Tertiary limestone, covering granite, with volcanic rocks near	Near Aubenas, Dep. d'Ardeche	......	66	....	....
	Bagnoles	Ditto	Nr. Mende, Dep. de Lozere	......	57	6,192	....
	Digne	Limestone in inclined strata	Con. with the Alps of Dauphiny: Dep. des Basses Alpes	......	Bassin de l'Etuve 59.25	....	....
France. From Lat. 44° to 42°. W. Long. 4° to E. Long. 4°. Assumed mean temp. 60° Fahr.	Greoulx	Limestone in inclined strata	Dep. des Hautes Alpes	......	41·75	....	....
	Aix	Jura limestone, dislocated and inclined	Dep. des Bouches du Rhone	......	Sextius 39·0	....	....
	Balaruc	Jura limestone, near the volcano of Agde	Nr. Cette, Dep. d'Herault	......	Varying from 66 to 52	....	....
	Sylvanes	Granite	Connected with the chain of the Pyrenees: Near St. Affrique, Dep. de l'Aveyron	......	48	....	....
	Rennes............	Sandstone, breccia, and limestone, belonging to the coal formation, highly inclined	Near Limoux, Depart. d'Aude	......	Bainfut 53·0	....	....
	Campagne	Ditto	Ditto	......	21·5	....	....
	St. Paul de Fenouilhades	From a fault in limestone, covering slate	Near Caudies, Dep. d'Aude	......	21·5		
	Arles	Granite near its junction with limestone	Dep. de Pyrénées Orientales: Valley of the Haut Segre	9	Petit Escaldadou 85· 3 F.	36,357	
	Preste	Granite		......	Source d'Apollon 71·0	10,888	....
	Vernet	Junction of granite with stratified rocks	Valley of the Tet	17	Source interieur 72·2	2,455,668	....
	Molitz	Granite		......	Grande Source 40	3 springs 1,170	....
	Thuez	Granite and serpentine .		27	Source du Torrent Real 111·5	....	....
	St. Thomas	Mica slate, resting on a quartzose granite		......	No. 1......... 75		
	Canavilles	Mica slate, resting on a quartzose granite		......	69·5		

Springs. (Continued.)

Gases evolved and their relative proportions one to the other.				Gaseous contents.	Solid contents.		
Carbonic acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
				C.In.	Grs.		
......	......	......	....	Carbonic acid.			
......	......	......	....	Ditto	....	Carb., sulph., and mur. of soda.	
......	......	......	....	....	....	Carb., mur., and sulph. of soda.	
......	......	......	....	....	....	Mur. of magnesia and sulph. of lime.	
......	......	......	....	Sulphur. hydr..........	14·3	Sulphate of magnesia and lime, mur. of soda.	
......	......	......	....	Carbonic acid, sulph. hydrogen	25·32	Mur. of soda and magnesia.	
......	......	......	....	....	1·5	Carb. of magnesia and lime, sulph. of lime	Robert.
......	......	......	....	Carbonic acid 6·0	....	Mur. of soda and magnesia, and lime, carb. of lime	Figueir.
......	......	......	....	....	....	Mur. and sulph. of soda and magnesia.	
wholly	......	......	....	Carbonic acid	12·0	Oxide of iron.	
......	......	wholly	Anglada ...	Nitrogen and oxygen	2·0	Sulphuret of sodium, soda, caustic and combined with sulphuric acid	Anglada.
......	......	wholly	Ditto	....	0·978	Ditto	Ditto.
......	......	wholly	Ditto	....	1·311	Ditto	Ditto.
......	......	wholly	Ditto	....	1·326	Ditto	Ditto.
......	......	......	....	....	0·984	Ditto	Ditto.

Catalogue of Thermal

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours of Water.	Gas.
France. N. Latitude 44° to 42°. W. Longitude 4° to E. Longitude 4°. Assumed mean temperature 60° Fahr.	Sorede	From granitic pebbles	Connected with the chain of the Pyrenees; Dep. des Pyrénées Orientales; Arrond. de Ceret	......	Font Agre 9°	....	....
	Reynez	Mica slate	Arrond. de Ceret	......	Beu Calde 23·75	....	....
	Enn	Mica slate, resting on a saccharoid limestone	Arrond. de Prades	......	62	....	....
	Thuez	Junction of granite with limestone along a line of fissure	Arrond. de Prades	......	Source d'Exhalade 71	....	....
	Escaldas	Granite near its contact with slate	Valley of the Tech	47	Buvette 47·1 F.	28,609	535
	Dorres	Like Escaldas	Valley of the Tech	48	44·4 F.	....	....
	Los	....	Valley of the Tech	......	Source Gervais 24·25	....	....
	Ax	At the boundary line of granite and slate	Dep. d'Arriege, near Tarascon	25	Source des Canons 108·0	....	....
	Ussat	Limestone, with granite contiguous	Ditto, ditto	......	40·0	18,000	....
	Lez	Granite	Valley of	......	Source A 26·4 F.		
	Bagnères de Luchon	Granite near its junction with clay-slate	Dep. de HauteGaronne	20	Grotte superieur 79·1 F. 77·75	....	....
	Encausse	Limestone	Dep. de HauteGaronne, nr. St. Gaudens	......	6·0	....	....
	Bagnères de Bigorre	Limestone resting on clay-slate, with patches of granite near it	Dep. des Hautes Pyrénées	20	Dauphin 59·0 F.	....	....
	Capvern	Limestone	Dep. des Hautes Pyrénées, near Bagnères de Bigorre	......	15·	....	....
	Barège	Clay-slates, with hornblende; granite not far distant	Dep. des Hautes Pyrénées	42	Grande Douche 51·9 F.	....	....
	St. Sauveur	Slaty limestone, with hornblende slates adjacent; granite not far distant	Ditto	25	La Houtalade 8·5 F.	....	....
	Cauterets	Clay-slate, with hornblende in nearly vertical beds, near the contact with granite	Ditto	31	Source des Œufs 70·1 F.	Source de Pauze alone 1,326 All the springs 12,240	Source de Pauze 61·8

...prings. (Continued.)

...es evolved and their relative ...oportions one to the other.				Gaseous contents.	Solid contents.		
	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
	......	......	Anglada ...	Carbonic acid	Grs 6·8	Carb., sulph., and mur. of soda; *oxide of iron*	Anglada.
	0	0	Ditto	....	....	Sulph. of lime and soda, mur. of soda	Ditto.
	0	0	Ditto	....	*Very small*.........	Ditto	Ditto.
	0	0	Ditto	....	....	Ditto	Ditto.
	0	100	Ditto	....	1·02	Hydrosulphuret of soda, with soda and potass, caustic? sulph. of soda?	Ditto.
	0	100	Ditto	....	....	Ditto	Ditto.
	0	100	Ditto	....	....	Ditto	Ditto.
	......	......	....	....	....	Hydrosulphuret of sodium, caustic soda.	
	......	......	....	....	....	Sulph. and mur. of mag.	
	......	......	....	....	2·2	Sulphuret of sodium, carb., sulphate, mur. of soda.	
	......	......	....	Carbonic acid	....	Sulph. of lime, magnesia, and soda.	
	......	......	....	Ditto	Source de la Reine 1·37	Sulph. of lime, magnesia, and soda, mur. of magnesia and soda	Gauderex.
	......	......	....	Ditto	8·0	Sulph. of lime and mag.	Save.
)	0	100	Longchamp.	....	2·3	Sulphuret of sodium, caustic soda, sulph. of soda.	
	......	......	....	....	1·1	Ditto.	
)	0	100	Longchamp.	....	Le Pré 29.		

Catalogue of Therma

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic fee evolved in 24 hours	
						Water.	Gas.
France. N. Lat. 44° to 42°. W. Long. 4° to E. Long. 4°. Assumed mean temp. 60° Fahr.	Eaux Bonnes ...	In a valley of disruption, from highly inclined beds of limestone, near its contact with granite	Connected with the chain of the Pyrenees: Dep. des Basses Pyrénées	26	Source Vieille 32·0° 31·4 F.	....	....
	Eaux Chaudes ...	In a valley of disruption, at the junction of granite, with inclined beds of limestone	Ditto	22	Clot 34·6 F.	3,924	....
	Cambo	Clay-slate in inclined strata, resting on granite	Ditto	......	10.	....	....
	Dax	Compact limestone, with trap near it	Dep. des Landes	......	82·25		
	Barboutan	Tertiary ?..................	Dep. de Gers	......	44.	....	....
	Castera-vivant...	Tertiary ?..................	Ditto	......	25	....	....
Switzerland. N. Lat. 48° to 46°. E. Long. 6° to 10°. Assumed mean temp. 49°.	Pfeffers............	Disrupted beds of limestone	Canton of St. Gall	23	From 50·5 to 51·0 48·9 F.	Very variable, greatest in summer (=429,120), least in winter	....
	Vals	Clay slate and compact limestone	Valley of Lugnitz, canton of Grisons	......	14	....	....
	Weissenburg ...	....	Canton of Berne	27	32·5 F.	1,423	....
	Loueche	Disrupted beds of limestone, with granite not far distant	Canton of Valais	47	74·1 F.	161,364	....
	Baden	....	Canton of Argau	10	St. Verene 78·0	One spring 186,325	....
	Schinznach	....	Ditto	10	39·25 varying a degree or so	....	....
	Yverdun	....	Canton of Neuchâtel	13	27	....	....

prings. (Continued.)

es evolved and their relative proportions one to the other.			Gaseous contents.	Solid contents.		
Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
			C.In.	Grs.		
......	......	....	....	0·949	Sulphuret of sodium, caustic soda, sulph. of lime.	
......	......	....	....	6·000	Sulph. of magnesia, mur. of soda and magnesia	Poumier.
......	......	....	....	1·5	Sulph. and mur. of mag.	
......	......	....	Sulphuretted hyd.			
......	......	....	Ditto	....	Sulph. of soda and mur. of lime.	
......	......	....	....	2·61	Sulphate of soda and magnesia, muriate of soda and magnesia	Capeller.
......	......	....	....	17·3	Sulph. of lime and soda, carbonate of lime	Ditto.
......	......	....	Carbonic acid	21·1	Sulphates of lime, soda, and magnesia	Brunner.
0	100	Ure	Ditto	21·47	Sulphate of lime, magnesia, and soda	Morell.
......	......	....	Ditto 2·56 Sulphuretted hyd.	32·29	Sulph. of lime, muriate of soda and mag., sulph. of soda	Bauhoff.
......	......	....	Ditto 6·0 Carbonic acid 2·3	27·0	Sulphate of lime and soda, mur. of soda and mag., oxide of iron	Ditto.
......	......	....	....	0·983	Muriate of soda, sulph. of lime, carb. of soda	Morell.

Catalogue of Thermal

Country.	Name of the place where the spring occurs.	Geological position.	Geographical position.	Height in 100 ft. above the sea.	Name of the hottest spring and its excess of temperature above that of the locality.	Number of cubic feet evolved in 24 hours o[f] Water.	Gas.
Savoy. N. Lat. 46° to 45°. E. Long. 6° to 7°. Assumed mean temp. 50°.	St. Gervais	Talc slate..................	Near Sallenche	17	56·50	1,440	....
	St. Martino	Gritty dark-coloured sandstone	Near Worms, in the canton of Valteline	50	Varies from 68 to 46	....	....
	Aix	....	Near Chambery	......	67·0	....	....
	Bonneval	....	Tarantaise, nr. BurgSt.Maurice	......	....	....	....
	La Perrier	....	Near Moutiers, Tarantaise	14	49·5	....	....
	Moutiers	....	Tarantaise ...	......	47·25	....	....
	Echaillon.........	....	Maurienne ...	......	39·6		
	Courmayeur ...	....	Valley of Aoste	......	14·5	....	....
	St. Didier.........	....	Vallée d'Aoste	......	20·25	....	....

Italy.
N. Lat. 45° to 43°. Mean temp. 60°.

Piedmont ...	Acqui, excess of temperature	°
	Acqua della Bollente	107· F.
	Valdieri	86·75
	Vinadio	93·50
	Craveggia	21·50
	Bobbio..........................	
	Acqua Santa, near Genoa ...	17·
	La Penna, near Voltri	17.
	Roccabigliera, near Nizza...	21·5
Lombardy...	Abano, near Padua............	121·0
Tuscany.....	Lucca	64·
	Monte Cerboli..................	50·
	Pisa	46·
	Monte Catini	22·*
PapalStates.	Nocera..........................	

Italy.
N. Lat. 43° to 40°. Mean temp. assumed to be 6[0°]

Bagni de San Filippo..........................	49·°
Bagni de Vignone (the Reservoir).........	
Viterbo, Bullicami (the Lake)	19·
Civita Vecchia	25·
Civillina	
Puzzuoli, Temple of Serapis	37·5
Baths of Nero	121·2
Pisciarelli...	51·0
Torre del Annunziata..........................	26·

* At the Reservoir evolves gas consisting

...prings. (Continued.)

...ses evolved and their relative ...roportions one to the other.				Gaseous contents.	Solid contents.		
...acid.	Oxygen.	Nitrogen.	According to	In a pint of the water.	Total amount of ingredients in a pint of the water of the spring most strongly impregnated.	Nature of the more abundant and of the more active ingredients present.	According to
...	......	chiefly	Daubeny ...	Carbonic acid	Grs. 45·47	Sulphate of soda and lime, mur. of soda and mag.	Pictet.
..	......	......	....	....	33·3	Sulphate of soda and lime, carb. of lime and mag.	Demagre.
0	0	100	Gimbernat .	Carbonic acid, sulph. hydrogen	Sulphur spring 4·0	Sulphate of lime, soda, and mag., muriate mag. and soda	Thibaud.
2	0	88	Daubeny.				
0	0	90	Socquet ...	Carbonic acid, sulph. hydrogen, trace	58·1	Sulphate of lime, soda, and mag., mur. of mag.	Socquet.
...	......	......	....	....	....	A strong brine spring.	
...	......	......	Daubeny ...	Carbonic acid	....	Mur. soda and mag., sulph. of lime and alumina, oxide of iron	Ruffinelli.
...	......	......	Ditto	Ditto	....	Mur. soda, sulph. of mag. and lime, oxide of iron	Ditto.

...ands connected geographically with Italy, and in the same latitude, viz.:

N. Lat. 43° to 40°. Mean temp. 61°.

...rgitello, *Ischia*, varies from 83°·5 to 94°·5...	88° F.
...qua de Cappone, *Ischia*	27·25
...mitello....................................	44·00
...tara	62·00
...gni d'Ischia	52·00
... Restituta	62·00
...quinas, *Sardinia*........................	98·
...qua Cotta	44·
...netutti	39·
...rdara	50·
...itera, *Corsica*.............................	61·
...agno	57·

Italy and adjacent islands.

N. Lat. 40° to 37°. E. Long. 13° to 19°.

Assumed mean temp. 63°.

Santa Eufemia, in *Calabria*	°
Bagni di Lipari, *Island of Lipari*	
Termini, *Sicily*	47·
Trepani, sulphureous, hot	
Sciacca, Baths of Santa Cologero	63·

...of 10 carbonic, 2 oxygen, 98 nitrogen. (*Daubeny.*)

Spanish Peninsula.

N. Lat. 41° to 36°. W. Long. 9° to E. Long 1°.
Mean temp. not sufficiently ascertained.

In Spain .... Along the line of the Pyrenees are several, especially in Catalonia, near Barcelona; and at Albama, near Catalayud in Aragon.

Near the volcanic hills of Murcia—Fuente de Buzot, near Alicant (104° F.), and Archena, near Murcia.

At the foot of the Sierra Noveda range—that near Merida, in Estremadura.

Amongst the mountains of Grenada—the baths of Javal-Cohol, near Baeza; those near Alhama; and those near Almeria.

Amongst the mountain-chain of the Basque provinces—Calda di Bonar, near Leon; and Orense, in Galicia.

In Portugal.. *Province of Minho*—San Antonio das Taipas, or Caldas das Taipas, near Guimarens, sulphureous 91° F.; 2. Caldellas de Rendusa, 89°; 3. Canaveres, near Guimarens, sulphureous, 93°·2; 4. Guimarens, sulphureous, 138°; 5. Monçao, near Ucana, 109°·4.

Province of Tra los Montes—1. Carlao, Villa-real, sulphureous, 92°·8; 2. Chaves, near Braganza, alkaline, 141°·8; 3. Pombal d'Anicaes, near Torre de Moncorvo, sulphureous, 95°; 4. Ponte de Cavez, Villa-Real, sulphureous, 74°·75; 5. Rede de Corvaceira, de Moledo, de Panaguiao, 98°·6.

Province of Beira—1. Alcafache, near Viseu, 98°·6; 2. Aregos, near Lamego, 142°·25; 3. Canas de Senhorim, near Viseu, 93°·2; 4. Carvalhal, near Viseu, 98°·6; 5. Santa Gemil, or Lagiosa, near Viseu, 120°·2; 6. San Pedro Dosul, near Viseu, 153°·5; 7. Penagarcia, or Caldas di Monsortinho, near Castelbranco, 68°; 8. Penamacon, 68°; 9. Prunto, Azenha, or Vinha da Rainha, near Coimbra, 89°·6; 10. Ranhados, near Pinhel, 107°·6; 11. Rapoila de Coa, near Castelbranco, 93°·2; 12. Unhaes da Serra, near Guarda, 87°·8.

N.B. All the above are sulphureous, excepting Penamaçon.

Province of Estremadura—1. Caldas da Rainhas, near Alemquer, sulphureous, 93°·2; 2. Cascaes, or Estoril, Torres Vedras, 84°·2; 3. Gaieiras, near Alemquer, sulphureous, 91°·4; 4. Leyria, 77°; 5. Lisbon, sulphureous, 86°; 6. Miorga, Alcobaça, 82°·4; 7. Povea de Coz, Alcobaco, 77°; 8. Rio-Real, Alemquer, sulphureous, 75°·2; 9. Torres Vedras, 111°·2; 10. Agua santa de Vimeiro, 78°·8.

Province of Alentijo—1. Cabeço de Vide, 80°·6.

Province of Algarves—1. Monchique, near Lagos, sulphureous, 92°·7; 2. Tavira, 75°·50.

Provinces of European Turkey.

N. Lat. 46° to 41°. E. Long. 17° to 29°.

Mean temp. not sufficiently ascertained.

Line of thermal waters extends from north to south in Servia, at the foot of the chain of mountains which connects the Carpathians with the ridge of the Balkan, and through which the Danube forces its way between Moldava and Gladova. The line of hot springs begins at Mehadia, in the Bannat, and extends south beyond Nizza in Servia.

A second line may be traced running east and west at the foot of the Balkan. The hottest has a temperature of 162°·5.

A third group exists in southern Macedonia, near Salonichi and Serres. They are mostly sulphureous.

Greece and its Islands.

N. Lat. 41° to 36°. E. Long. 20° to 27°.

Mean temp. not ascertained.

A group of thermal springs at the base of Mount Olympus, of which that at the Pass of Thermopylæ is the only one whose temperature is ascertained. This found by Clark to be 113°.

Hot bath of Venus, east of Corinth.

Korantzia, south of Mount Geranicus, near the Gulf of Corinth, gaseous eruptions and a spring at 87°·8.

At Venetiko, west of Lepanto, a sulphureous thermal spring, called Taphoi (Tombs of Nessus).

Six leagues from Patras, a saline thermal spring, 96°·8.

In the Morea, near Methone, in the ancient Argolis, near the base of an extinct volcano, and in the Archipelago, in the islands of Negropont, (Lelantho, near the ancient Chalcis,) Milo, Thermia, and Lemnos, are thermal waters*.

Iceland.

N. Lat. 63° to 67°. W. Long. 12° to 25°.

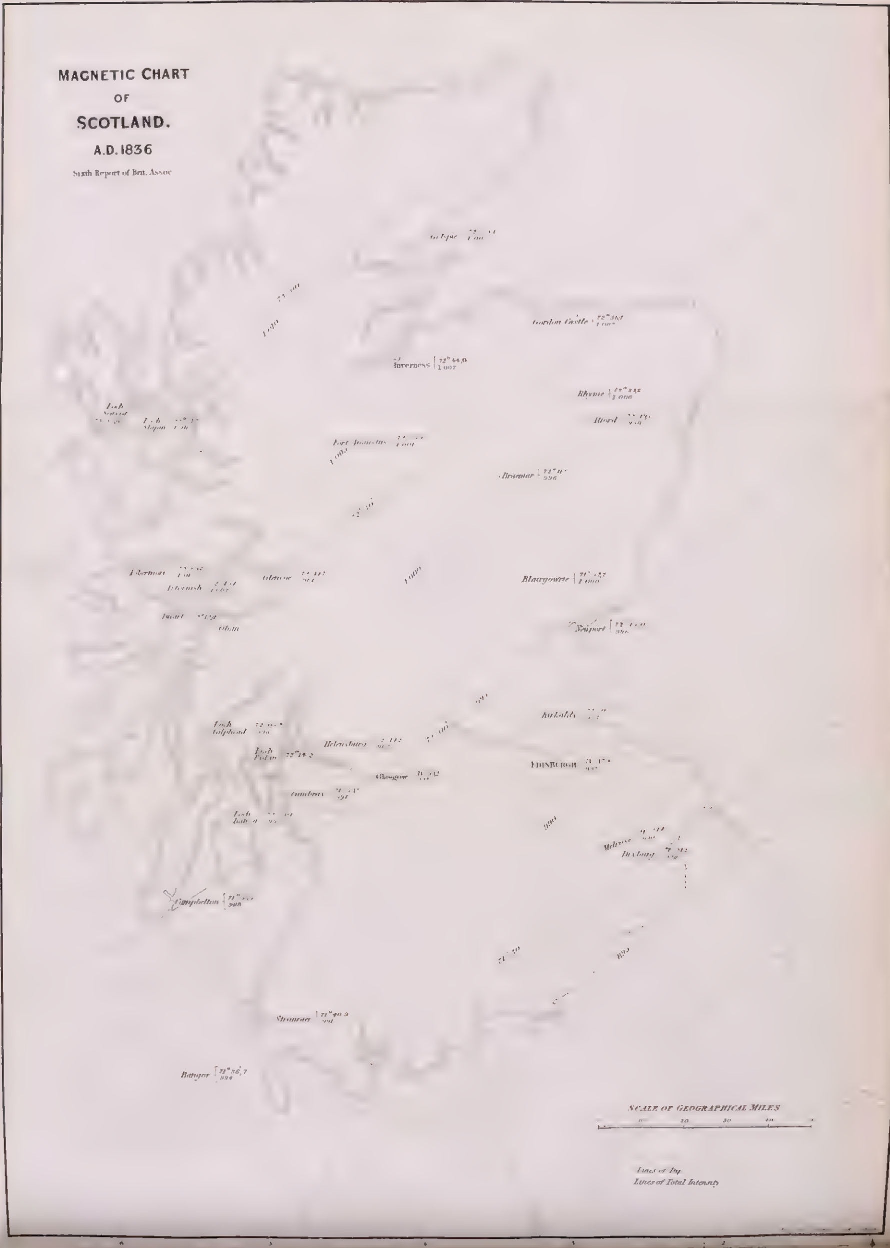
Mean. temp. 37°·4 Fahr.

A very numerous class of sulphureous waters, with a high temperature, in that part of the island, where trachyte exists, and volcanic eruptions at present take place.

A second class of thermal waters of a lower temperature, and impregnated only with carbonic acid gas, in the volcanic promontory of Sneefield-Syssel, where igneous operations have ceased†.

* Consult Virlet, *Expedition Scientifique de Morée.*

† See Krug von Nidda in *Edinb. New Phil. Journ.*, vol. xxii.


MAGNETIC CHART
OF
SCOTLAND.
A.D. 1836
Sixth Report of Brit. Assoc.
Gordon Castle
Inverness $\left\{ \begin{matrix} 72^\circ 44,0 \\ 1.007 \end{matrix} \right.$
Rhynie
Fort Augustus
Braemar $\left\{ \begin{matrix} 72^\circ 11' \\ 996 \end{matrix} \right.$
Blairgowrie
Newport
Kirkaldy
Helensburg
Glasgow
Cumbray
EDINBURGH
Melrose
Campbelton
Stranraer $\left\{ \begin{matrix} 71^\circ 40,3 \\ 991 \end{matrix} \right.$
Bangor $\left\{ \begin{matrix} 71^\circ 36,7 \\ 994 \end{matrix} \right.$
Oban
SCALE OF GEOGRAPHICAL MILES
10
20
30
40
Lines of Dip
Lines of Total Intensity

Observations on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland. *By Major* Edward Sabine, *R.A., F.R.S., &c.*

[With a Plate.]

THE observations, which form the subject of the following paper, were made during a leave of absence with which I was indulged from military duty in Ireland, in the summer of 1836.

I was indebted for the opportunity of extending them to several stations in the Western Islands, to the interest felt in the subject, and to the private friendship of James Smith, Esq., of Jordanhill, President of the Andersonian Institution at Glasgow, who devoted a cruise of his yacht to the purpose.

I. *Observations of Dip.*

The needle employed in making the observations of dip is the one characterized as S (2) in the account of the Magnetical Observations in Ireland (*Fifth Report of the British Association*, pp. 141—149). It was made for me by Robinson, of Devonshire-street, London, to be used on Professor Lloyd's principle of determining both dip and intensity by the same needle. Its length is $11\frac{1}{2}$ inches. The only peculiarity in the apparatus in which it is used is, that the agate planes of support are rendered horizontal by a detached circular brass plate, ground for the purpose, and carrying a small spirit level. The plate is placed on the planes themselves, and the foot-screws are adjusted until the level remains stationary whilst the plate is turned in every direction; and it is then removed. There are also levels attached permanently to the circle, which serve to detect any change which might subsequently take place in the horizontality of the planes during the course of the observation. The mode of observation of the dip is the same as usual. The number of readings employed in each result is noted in the tables, the reading of each pole being considered as a distinct reading. The needle was removed from its supports by Ys, and lowered afresh between each pair of readings; and the face of the circle and of the needle were changed round frequently in the course of each determination.

In a needle on Professor Lloyd's principle, the poles are not changed in each observation of the dip; consequently a correction is required to be applied to all the results obtained with it

for the effect of the momentum of the needle, unless the centres of gravity and of the axle should be strictly coincident, which is a nicety of adjustment rarely if ever attained. The amount of this correction is learnt by comparing the dip observed at some one station with that needle, and with others of the ordinary construction in which the poles are changed in each determination. The following observations, made at Limerick, furnish this correction.

1. Needle S (2).

Date.	No. of Sets.	No. of Readings in each Set.	Dip observed.	Reduced to Jan. 1836.	
July 1835	4	80	71° 16′·93	71° 15′·68	
December 1835	3		71 14·6	71 14·60	
February 1836	1	40	71 13·4	71 13·7	
May 1836	2	80	71 12·0	71 13·25	
Mean, weight being allowed proportioned to the number of sets.				71 14·7	

2. With other needles.

Date.	No. of Sets.	No. of Readings in each Set.	Dip observed.	Reduced to Jan. 1836.	
November 1833	4	48	71° 11′·7	71° 05′·4	Meyer's Needle.
August 1834...	2	96	71 03·5	70 59·5	Dollond S (1).
May 1836	1	128	71 00·57	71 01·8	Dollond S (1).
May & June 1836	2	128	71 00·05	71 01·4	Meyer's Needle.
Mean, weight being allowed proportioned to the number of sets.				71 02·8	

Whence it results that — 12′ is the correction for the dips observed with Needle S (2); and from the small amount of this correction it may be regarded as constant within the limits comprised by the observations in Scotland. The dips inserted in the

* In Meyer's needle, by the use of spheres of different magnitudes in the different sets, the results are obtained from arcs differing very widely from each other, and in which the needle rests on very different parts of the axle. The avoidance thereby of any constant error, caused by the imperfect curvature of some particular parts of the axle, is one of the advantages of a needle on this construction which ought not to be lost sight of, or unattended to in observing with it. The partial results may be wider if the axle be not very truly ground, but the mean is more likely to be free from error.

following table have therefore been diminished 12′ from the original observations.

TABLE I.

Observations of Dip, Needle S (2).

Station.	Lat.	Long.	Date.	No. of Readings.	Dip.	Place of Observation.
	° ′	° ′			° ′	
Dublin	53 21	6 15	July 22, 23.	240	71 01·1	Provost's Garden, Trinity College.
Helensburgh .	56 0	4 41	July 28.	160	72 15·9	Seabeach.
Gt. Cumbray .	55 48	4 50	July 30.	80	71 58·7	NE. end of the Island.
Loch Ridan ...	55 57	5 10	Aug. 5.	52	72 14·2	Eastern side of the Loch.
Loch Gilphead	56 01	5 28	Aug. 7.	104	72 05·2	Wood near the Canal.
Castle Duart...	56 31	5 45	Aug. 9.	96	72 12·3	Grounds of Castle Duart.
Tobermorie ...	56 38	6 01	Aug. 10.	80	73 05·2	Seabeach S. of the Town.
Loch Scavig ...	57 14	6 07	Aug. 12.	48	73 02·8	Near the entrance of Loch Coruisk.
Loch Slapin ...	57 14	6 02	Aug. 14.	48	72 59·7	E. side of the inner Loch.
Artornish	56 33	5 48	Aug. 16.	48	72 40·4	Limestone Point S. of the Castle.
Glencoe	56 39	5 07	Aug. 17.	72	72 14·7	Grove near the Village.
Fort Augustus	57 08	4 40	Aug. 19.	72	72 37·9	Field near the Canal.
Inverness	57 27	4 11	Aug. 20.	64	72 44·1	Grounds of Abertorf.
Golspie	57 58	3 57	Aug. 23.	236	72 53·1	Wood near the Inn.
Inverness	57 27	4 11	Aug. 24.	48	72 43·9	Grounds of Abertorf.
Gordon Castle	57 37	3 09	Aug. 25.	88	72 38·4	Grounds of the Castle.
Rhynie	57 20	2 50	Aug. 26.	88	72 23·2	Field near the Inn.
Alford	57 13	2 45	Aug. 27 & 29.	160	72 19·5	By the River in front of the Manse.
Braemar.........	57 01	3 25	Aug. 30.	80	72 11·7	Field near the Inn.
Blairgowrie ...	56 36	3 18	Aug. 31.	80	71 52·25	Field N. of the Town.
Newport.........	56 25	2 55	Sept. 1.	136	72 14·95	Field inland of the Village.
Kirkaldy	56 07	3 09	Sept. 3.	88	72 08·5	Mr. Fergus's Garden.
Melrose.........	55 35	2 44	Sept. 6.	80	71 34·45	Riverside, E. of the Abbey.
Dryburgh	55 34	2 39	Sept. 7.	80	71 31·2	Tweed side.
Edinburgh ...	55 57	3 11	Sept. 8.	80	71 47·9	Botanic Garden.
Glasgow.........	55 51	4 14	Sept. 9.	104	71 59·2	Botanic Garden.
Helensburgh...	56 0	4 41	Sept. 13.	80	72 12·6	Field East of the Town.
Loch Ranza...	55 42	5 17	Sept. 16.	130	72 20·45	East side of the Loch.
Campbeltown .	55 23	5 38	Sept. 16.	80	71 53·5	S. side of the Harbour.
Stranraer	54 55	4 59	Sept. 18.	80	71 40·93	Seabeach E. side of the Loch.
Bangor	54 40	5 40	Sept. 21.	80	71 36·7	Grounds of the Castle.
Dublin	53 21	6 15	Oct. 4.	80	71 00·7	Provost's Garden, Trinity College.

The latitudes and longitudes are taken from the map of Scotland published by the Society for Diffusing Useful Knowledge.

The stations and dips enumerated in the preceding table require to be combined, according to the method exemplified in the Irish Magnetical Report, in order to determine the angle which the isoclinal lines in Scotland make with the meridian; and the distance apart of the isoclinal lines which correspond to certain differences of dip. For this purpose some one station may be selected as the origin of the coordinates of distance of the other stations; and at that station the dip should be ascertained with all possible accuracy. In the progress of the observations, I had occasion frequently to remark the disturbance in the direction of the needle caused by the vicinity of rocks of igneous origin. Rocks of this nature are so extensively and generally diffused throughout Scotland, as to make it doubtful whether any station could be selected, which might be confidently assumed to be entirely free from local disturbance of this na-

ture; and at which consequently the dip, observed with sufficient care and repetition, might be presumed to be due solely to the geographical position of the station. With this view, I have deemed it preferable to take an arbitrary geographical position, nearly central in regard to Scotland and to the body of the observations, and to compute the most probable dip for that position by a combination of the results at all the stations of observation. The central position adopted is lat. 56° 27′, long. 4° 25′ W. of Greenwich. The coordinates of distance in latitude and longitude of the several stations from the central position, expressed in geographical miles, are inserted in the subjoined table, together with the observed dips at each station, in degrees and decimals of a degree.

Table II.

Station.	Diff. of Lat.	Diff. of Long.	Dip.	Station.	Diff. of Lat.	Diff. of Long.	Dip.
Loch Scavig ..	+47	+55	73°·047	Loch Ridan ...	— 30	+25	72°·237
Loch Slapin ..	+47	+52	72·995	Blairgowrie ..	+ 9	—37	71·871
Golspie	+91	—15	72·885	Helensburgh ..	— 27	+ 9	72·265
Inverness	+60	— 8	72·735	Helensburgh ..	— 27	+ 9	72·210
Inverness	+60	— 8	72·732	Lock Ranza ..	— 45	+29	72·341
Tobermorie ..	+11	+53	73·087	Cumbray	— 39	+14	71·978
Fort Augustus	+41	+ 8	72·632	Campbeltown .	— 64	+42	71·892
Gordon Castle	+70	+41	72·640	Newport	— 2	—50	72·250
Astornish	+ 6	+46	72·673	Glasgow.......	— 36	— 6	71·987
Castle Duart..	+ 4	+44	72·213	Kirkaldy......	— 20	—42	72·142
Glencoe......	+12	+23	72·245	Edinburgh....	— 30	—41	71·798
Rhynie	+53	—51	72·387	Bangor	—107	+43	71·612
Braemar......	+34	—33	72·195	Stranraer	— 92	+20	71·692
Alford........	+46	—54	72·325	Melrose......	— 52	—57	71·574
Loch Gilphead	—23	+35	72·087	Dryburgh	— 53	—60	71·520

We have then three unknown quantities to seek; viz. δ = the dip at the central position; u = the angle which the isoclinal line passing through the central position makes with the meridian; and r = the coefficient determining the rate of increase of the dip in the normal direction.

Putting $r \cos u = x$, and $r \sin u = y$, the equations of condition to be combined by the method of least squares are of the following form:

Loch Scavig . . . . $73{\cdot}047 = \delta + 55.x - 47.y,$
Loch Slapin . . . . $72{\cdot}995 = \delta + 52.x - 47.y,$
Golspie . . . . $72{\cdot}885 = \delta - 15.x - 91.y,$

and so forth, there being as many equations as there are stations of observation. Or if we diminish by an equal amount (71°, for instance,) each of the observed dips, for the convenience of working with smaller numbers, and make $\delta = 71° + \delta'$, these equations become,

$$2{\cdot}047 = \delta' + 55.x - 47.y,$$
$$1{\cdot}995 = \delta' + 52.x - 47.y,$$
$$1{\cdot}885 = \delta' - 15.x - 91.y,$$

and so forth. The sum of the 30 equations, representing the sum of the equations severally multiplied by the coefficient of δ', is

$$+\,38{\cdot}238 = +\,30\,\delta' + 4.x + 56.y \quad . \quad . \quad . \quad \text{(A)}$$

Next, multiplying the same equations severally by the respective coefficients of x, we have

$$+\,112{\cdot}585 = +\,55\,\delta' + 3025.x - 2585.y,$$
$$+\,103{\cdot}740 = +\,52\,\delta' + 2704.x - 2444.y,$$
$$-\,28{\cdot}275 = -\,15\,\delta' + 225.x + 1365.y,$$

and so forth; the sum of these 30 equations being

$$+\,170{\cdot}00 = +\,4\,\delta' + 43084.x + 9660.y \quad . \quad . \quad \text{(B)}$$

And lastly, multiplying by the coefficients of y, we have

$$-\,96{\cdot}209 = -\,47\,\delta' - 2585.x + 2209.y,$$
$$-\,93{\cdot}765 = -\,47\,\delta' - 2444.x + 2209.y,$$
$$-\,171{\cdot}535 = -\,91\,\delta' + 1365.x + 8281.y,$$

and so forth; the sum being

$$-\,431{\cdot}82 = +\,56\,\delta' + 9660.x + 71514.y \quad . \quad . \quad \text{(C)}$$

The three final equations A, B, C, furnish by elimination the most probable values of the quantities sought. These are as follows:

$$\delta' = 1°{\cdot}288, \qquad x = +\,{\cdot}00557, \qquad y = -\,{\cdot}00780;$$

and from these we obtain the dip at the central station $\delta = 71° + \delta' = 72°{\cdot}288 = 72°\ 17'{\cdot}3$; the angle which the isoclinal line makes with the meridian $= -\ 54°\ 27'$; or its direction is from N. 54° 27′ E. to S. 54° 27′ W.; and the rate of increase of dip in the normal direction $= 0'{\cdot}575$ in each geographical mile, or 52·15 geographical miles to each half-degree of dip.

If now we substitute in the second members of the original equations the previously unknown values of δ, x, and y, we obtain the most probable dip due to the geographical position of each of the stations of observation; and, by transposition, the most probable amount of error in each of the observations,

whether it be regarded as error of observation or as resulting from local disturbance: bearing in recollection however, in the case of stations very distant from the central position, that the assumption upon which the equations are founded is probably not strictly correct, viz. of parallelism in the isoclinal lines, and of an uniform rate of increase of dip throughout Scotland.

The following Table exhibits the differences of observation and calculation; and shews the geological character of the surface rock at each of the stations, taken from Dr. Macculloch's Map, which, as far as I have had opportunities of judging, I have found everywhere most remarkably correct. When the observed dip is greater than the computed, the sign + is affixed, and − when less.

Table III.

Station.	Diff. observ'd and compd. Dip.	Geological Character.	Station.	Diff. observ'd and compd. Dip.	Geological Character.
Loch Scavig...	+ 5′·2	Hypersthene	Loch Ridan ...	+ 2′·0	Mica Slate.
Loch Slapin...	+ 3·0	Lias and Trap.	Blairgowrie ...	−17·1	Red Sandstone & Trap.
Golspie	− 1·7	Red Sandstone.	Helensburgh .	+ 6·5	Red Sandstone.
Inverness	+ 1·3	Red Sandstone.	Loch Ranza...	+14·5	Clay Slate & Granite.
Tobermoric ...	+25·7	Trap.	Cumbray	+ 5·1	Red Sandstone & Trap
Fort Augustus	− 1·2	Red Sandstone.	Campbelton ...	− 7·9	Red Sandstone & Trap
Artornish	+ 4·9	Limestone and Trap.	Newport	+15·3	Trap.
Gordon Castle	+ 2·0	Red Sandstone.	Glasgow.........	+ 0·9	Coal Series.
Castle Duart .	−21·1	Trap.	Kirkaldy	+14·6	Coal Series and Trap.
Glencoe	−15·9	Clayslate & Porphyry.	Edinburgh ...	− 1·7	Coal Series (Botanic Garden).
Rhynie	− 1·8	Gneiss.			
Braemar	−10·5	Granite.	Bangor	− 5·1	Trap.
Alford	− 1·2	Gneiss.	Stranraer	0·0	Clayslate.
Loch Gilphead	−13·0	Chlorite Slate.	Melrose.........	+ 0·5	Clayslate.
			Dryburgh......	− 1·3	Clayslate.

We may divide the differences shown in this Table into three classes; the first, of seven stations, wherein the differences are very great, amounting to 14′ and upwards; second, of eight stations, wherein the differences are more moderate, being between 14′ and 2′; and in the third class we may place the remaining twelve stations, at which the differences do not exceed 2′, being an amount which scarcely deserves to be called a difference. Referring now to the geological characters of the stations, we find, 1st, that all those of the first class, or where the differences exceed 14′, are stations either of trap rocks or of rocks of a similar nature; 2nd, that the stations of moderate differences are for the most part characterized also by the presence of igneous rocks either wholly or partially; and 3rd, that at all the stations at which the differences do not exceed 2′, the surface rock is sedimentary. It seems a reasonable inference from these facts, that instrumental errors make but a small portion of

the differences under the two first heads; and that we are warranted in considering such differences as evidencing real irregularities in the magnetic direction at the respective stations, caused by the presence of igneous rocks. We shall subsequently find that this inference is confirmed by the agreement of the intensities deduced by the horizontal and statical methods, when the dips *actually observed* are employed in the reduction of the horizontal vibrations, and in their extreme disagreement when the dips due simply to the geographical positions are employed.

A question here arises, how far the general results which we have derived, in regard to the isoclinal lines, from the combination of the dip observations, are likely to have been affected by these local irregularities; and it is satisfactory in this view to find, that a careful consideration of the errors in Table III. leads to the inference, that the disturbing cause, whatever it may be, has no uniform tendency, but that its effect is nearly as often to diminish as to increase the dip. It is indeed a consequence of the method of combination that the + and − errors should nearly balance; but had the effect of the disturbance at the igneous stations been uniformly to augment the dip (for instance), the sedimentary stations would all have appeared in defect, and all the igneous ones in excess; whereas the results at the sedimentary stations are indiscriminately in excess and in defect, but to a very inconsiderable amount; and at the igneous stations they are also indiscriminately in excess and in defect, but with differences of considerable amount.

After much consideration, it does not appear to me that a more satisfactory or probable conclusion would be arrived at, were any one or more of the stations now included in the calculation, to be withdrawn from it. Every observation of the dip has been included in the calculation, excepting two. One of these was at Oban, where I hastily observed the dip on a trap rock at no great distance from the wharf, whilst waiting for a steamer, and the result has been found to differ more than a degree from the dip assigned by calculation. I suspected the locality whilst making the observation; and had time permitted I should have removed the instrument to another spot, and repeated the observation. As it is I can only consider it too doubtful a result to be placed on the same footing with the others. The other rejected observation was of a very extraordinary nature. On a rock on which I landed, on the west side of the harbour at Loch Seavig, I observed a dip of 78° 10′·3, exceeding by 5° that which could be assigned to the geographical position. I had never before experienced an irregularity of dip

of similar amount, nor had I read of others who had done so. The weather was fine, and I had full time to assure myself that there was no instrumental mistake. After completing the series of four readings in each position of the needle, all of which corresponded well, I removed the instrument three several times to different places of observation distant ten or twelve yards, always obtaining the same result. The coincidence of the plane of the circle with the magnetic meridian was also verified by removing the compass needle to a fourth place considerably distant. The rock was hypersthene, remarkably traversed and intersected by trap veins, and certainly not an eligible spot for magnetic observations. Crossing to the other side of the harbour, to a spot less intersected by trap veins, near where the waters from Loch Coruisk fall into the sea, the needle gave the result 72° 59′·8, which has been included in the calculation, and differs only 5′·2 from the general deduction.

The lines of dip are laid down in the annexed chart agreeably to the general results which have been deduced. The dip at the central position in lat. 56° 27′ and long. 4° 25′ is 72° 17′·3, and the angle which the isoclinal lines make with the meridian at this station is 54° 27′. The isoclinal lines drawn in the map are those of 71° 30′, 72°, 72° 30′, and 73°, and are at distances apart of 52·15 geographical miles.

The near accordance in the amount of the angle with the meridian, and of the interval corresponding to half-degrees of dip, with the results obtained in Ireland in the preceding year, is confirmatory of both as near approximations. The angle with the meridian of the isoclinal lines in Ireland is 56° 48′, and the interval between the lines representing half-degrees of dip is 50·7 geographical miles. So far the correspondence of the observations of the two years and of the two countries is very satisfactory. The lines of 71° 30′ and 72° are the only ones that are common to both countries. If these lines are prolonged from the Scottish chart, they will enter Ireland to the south of the corresponding lines on the Irish chart; the line of 71° 30′ by a geographical space equal to about 9′ of dip, and that of 72° by a space equal to about 8′. In other words, the dip in the north-east part of Ireland, computed from the Scottish observations, would be about that number of minutes greater than if computed from the general result of the Irish observations; and in the north-west of Scotland the dip computed by the Irish results would be the same quantity less than by the Scotch results. Campbelton, Bangor, and Stranraer are frontier stations which may illustrate this. The dip at Campbelton deduced from the Irish results (dimi-

nished by 3′ for the decrease of dip between 1835 and 1836,) is 71° 53′·3; deduced from the Scottish results it is 72° 01′·4 The actual observation was 71° 53′·5, agreeing in this case with the Irish deduction. At Bangor the dip deduced from the Irish results is 71° 32′·3, and from the Scotch 71° 41′·6: the observed dip was 71° 36′·7, being intermediate between the two deductions. At Stranraer the deduction from the Irish results is 71° 31′·9, and from the Scottish 71° 40′·9; the observed dip being 71° 40′·9, which in this instance corresponds with the Scotch deduction. The discrepancy is not of greater amount than may easily disappear on a slight modification of the results in one or both countries, a modification which they may be expected to receive from more multiplied and extended observations. The true values of u and r are probably not exactly the same in the two countries; but it may be expected, when observations shall be sufficiently multiplied, that the deductions from the general results in both countries should agree in giving the same dip for the frontier stations.

We have hitherto no general series of observations of dip in England; but from the great pains which Captain James Clark Ross has bestowed on its determination in London, we may regard the result obtained by him in July 1835, viz. 69° 17′·3, as extremely free from instrumental error, and liable only to such differences from the dip strictly due to its geographical position, as may arise from local causes. The corrected dip for September 1836 would be about 69° 14′. The difference of dip between the central station in Scotland and in London, computed with the values of x and y resulting from the Scotch observations, is −3°·07, which being deducted from 72° 17′·3, leaves the computed dip in London 69° 10′·3. This is another confirmation that the Scotch results are near approximations, presuming, as is probable, that the values of u and r are nearly the same in England as in Scotland. In this instance the deduction from them is in defect; in the comparison with those from the Irish results it is in excess.

II. Intensity.

§. *By Professor Lloyd's Statical Method.*

The observations by this method were made with the same needle that was employed in determining the dip, viz. S (2). The method itself is described in the *Fifth Report of the British Association*, page 137, and more largely in the *Transactions of the Royal Irish Academy* for 1836.

It is important in all observations of intensity that the needle

should preserve its magnetic state unchanged or nearly so during the whole series of the observations. I had had this needle in my possession rather more than a twelvemonth, and had ascertained by frequent trials at the same station that its magnetic power was diminishing, but at a very slow and uniform rate, well admitting of interpolation. Being desirous of shortening as much as possible the period within which interpolation might be necessary, (which would naturally have been the interval between my leaving Dublin and my return to it,) I made more than the usual number of observations at Helensburgh, the first station I observed at in Scotland, five days only after I had observed in Dublin, designing to return to Helensburgh for the purpose of verification once, or oftener if occasion required, in the progress of the observations.

The first place to which I went from Helensburgh was the island of Great Cumbray. In disembarking the instruments, there being a good deal of sea, the case containing the needle fell from the table to the deck of the cabin. The needle was securely and immoveably fixed in the case, but the soft iron keeper which connected its poles was allowed a slight spring, arising from its own elasticity, to prevent its pressing too hard on the points of the needle. This occasioned a slight jar to take place; very slight, but still sufficient to be audible.

I conjectured immediately that the magnetism of the needle might be affected thereby; and the observations at Cumbray strengthened this conjecture, by showing a greater difference from the Helensburgh results than was likely to be due to the geographical distance between the stations. I returned to Helensburgh the following day, and on repeating the observations there, found that the counterpoise which had deflected the needle 89° 33′·9, now deflected it 91° 15′·6, showing that the magnetism of the needle had been lessened. Needles have been frequently remarked gradually to lose magnetism for some time after it has been first communicated to them, until they arrive at what appears to be a permanent condition for each particular needle; after which their magnetism remains steady. As far as can be conjectured, the jar above described seems to have brought this needle at once to its permanent state; for on returning to Helensburgh a third time, after an interval of 42 days, the observations being repeated, the same counterpoise again deflected the needle 91° 18′·7, a result almost identical with that obtained on returning from Cumbray. Further, on my return to Dublin early in October, I found, on carefully repeating the observations at the same place I had observed at in July, a difference in the magnetism of the needle almost

identical with the difference indicated by the results at Helensburgh before and immediately after the accident.

The ratio of the intensity of terrestrial magnetism between Dublin and Helensburgh as inferred from the results of July 22nd in Dublin and July 27th in Helensburgh, (being both previous to the accident,) is 1·0067 Helensburgh to 1 in Dublin; and as inferred from the results of August 2 and September 13 and 14 in Helensburgh, and October 4th in Dublin, (all subsequent to the accident,) the ratio is 1·0066 and 1·0059 Helensburgh, to 1 in Dublin. I have therefore taken the result in Dublin of the 4th October as comparable with all the observations made with this needle in Scotland, excepting the first results (July) at Helensburgh, and those are comparable with the first results (July) in Dublin. The same counterpoise was used throughout.

Before the values of the terrestrial magnetic force can be derived with accuracy from the angles of deflection, it is necessary to apply a correction for the variations of temperature of the needle itself in the observations at the different stations. The temperatures were observed by a thermometer placed in the circle with the dipping needle, and remaining during the course of the observations. For the purpose of ascertaining the value of this correction for needle S (2), the needle was suspended horizontally by fibres of unspun silk in an earthen vessel glazed at the top, standing in a larger earthen vessel, into which warm water might be poured to raise the temperature of the air and needle in the inner one. Several folds of flannel enveloped the whole apparatus, being drawn close round the upper part of the inner vessel, to keep the temperature steady for periods of sufficient duration. The temperature of the needle was shown by a thermometer suspended horizontally across it, not being in contact with any part of the apparatus. The needle was then vibrated alternately in the natural temperature of the room, and in the artificially raised temperature. An arc for measuring the extent of the vibration was placed beneath the needle, which was drawn out of the meridian, and released at pleasure by a suitable contrivance. The following observations were made at Limerick on the 30th of October.

Hour.	Therm.	Time of 100 Vibrations.	Means.
h. m.	°	s.	s. °
2 45 P.M.	49	646·64	
3 02 ,,	49	646·40	646·44 at 49.
3 17 ,,	49	646·27	
4 11 ,,	99	646·72	
4 28 ,,	99	646·53	646·55 at 90·5.
5 20 ,,	90	646·73	
7 15 ,,	74	646·00	
11 15 ,,	55	645·43	645·35 at 54·5.
11 38 ,,	54	645·26	

Here in the formula, $\alpha = \frac{2\,(\mathrm{T} - \mathrm{T}')}{\mathrm{T}'\,(\tau - \tau')}$, $\mathrm{T}' = 645^{s}{\cdot}89$; $-\ \mathrm{T}'\mathrm{T} = 0^{s}{\cdot}6$; $\tau - \tau' = 38^{\circ}{\cdot}7$. Whence $\alpha = {\cdot}000048$.

In this experiment the time of vibration, as may be seen, varied considerably in the cold temperatures at the commencement and at the close, and gave reason to believe that the change due to temperature might be overpowered by the diurnal variation of the force. The experiment was therefore repeated on the 15th November, as follows:

Hour.	Therm.	Time of 110 Vibrations.	Means.
h. m.		s.	s. °
4 58 P.M.	49	660·56	
5 16 ,,	49	660·87	661·04 at 49.
5 34 ,,	49	661·33	
5 50 ,,	49	661·40	
7 30 ,,	91	661·73	
7 48 ,,	89	661·67	661·77 at 87·6.
8 05 ,,	86	662·20	
8 24 ,,	84·5	661·47	
11 10 ,,	51·5	660·60	
11 25 ,,	51·0	661·40	660·98 at 51.
11 43 ,,	50·5	660·93	

Here $\mathrm{T}' = 661^{s}$; $\mathrm{T} - \mathrm{T}' = 0^{s}{\cdot}76$; $\tau - \tau' = 37^{\circ}{\cdot}6$. Whence $\alpha = {\cdot}000061$. This experiment appears more satisfactory than the preceding one; but as the results are so nearly the same, I have taken the arithmetical mean ·000055 for the value of α, which being multiplied by M, the modulus of the common system of logarithms, = ·000024 the coefficient of $\tau - \tau'$ in the correction for temperature.

In Table IV. the two last columns contain the value of the intensity computed from the angles of deflection, and from the

dip, and corrected for the variations of temperature inserted in the preceding columns. In the first of the final columns the ratios are expressed to unity in Dublin. In the last column the ratios are expressed to unity in London, and are the numbers in the preceding column multiplied by 1·0208, which has been ascertained by Mr. Lloyd to express the value of the intensity in Dublin, that at London being unity. (*Trans. R. I. Academy*, 1836.)

Table IV.

Intensity, Needle S (2).

Station.	Date.	Hour.	Therm.	No. of Readings.	Angle.	Intensity. Dublin = 1	London = 1
			°		° ′		
Dublin	July 22	7 to 8 A.M.	56	240	— 18 27·2	1·0000	1·0208
Helensburgh ...	July 27	11 to 1 P.M.	60	80	— 17 17·9	1·0067	1·0276
Gt. Cumbray ...	July 30	3 to 5 P.M.	64	144	— 18 31·9	1·0091	1·0301
Helensburgh ...	Aug. 2	12 to 3 P.M.	65	108	— 18 59·7	1·0066	1·0275
Tobermorie.....	Aug. 10	9 A.M.	70	28	— 15 29·3	1·0262	1·0475
Loch Slapin ...	Aug. 14	8 to 9 A.M.	56	48	— 15 59	1·0228	1·0441
Glencoe.........	Aug. 17	8 to 9 A.M.	57	60	— 17 50·8	1·0126	1·0337
Inverness	Aug. 20	2 to 4 P.M.	59	160	— 16 44·2	1·0189	1·0401
Golspie	Aug. 23	11 to 1 P.M.	51	96	— 17 08·4	1·0162	1·0373
Inverness........	Aug. 24	4 to 6 P.M.	58	92	— 16 53·7	1·0180	1·0391
Gordon Castle .	Aug. 25	4 to 5 P.M.	60	80	— 16 52·4	1·0182	1·0393
Alford	Aug. 27	5 to 7 P.M.	57	100	— 18 22	1·0097	1·0307
Braemar.........	Aug. 30	7 to 8 A.M.	44	56	— 18 40·1	1·0072	1·0281
Blairgowrie	Aug. 31	3 to 5 P.M.	59	120	— 18 06·1	1·0112	1·0321
Newport	Sept. 1	Noon	60	40	— 18 40·8	1·0080	1·0290
Kirkaldy	Sept. 3	Noon	60	48	— 18 37·7	1·0082	1·0292
Melrose.........	Sept. 6	4 to 6 P.M.	51	80	— 19 43·7	1·0013	1·0222
Dryburgh	Sept. 7	3 to 5 P.M.	56	80	— 19 56·1	1·0003	1·0211
Edinburgh	Sept. 8	5 to 6 P.M.	55	40	— 19 24·0	1·0035	1·0245
Glasgow.........	Sept. 9	11 to 12 A.M.	56	80	— 19 24·0	1·0036	1·0246
Helensburgh ...	Sept. 13 & 14	12 to 3 P.M.	64	80	— 19 06·1	1·0059	1·0268
Loch Ranza ...	Sept. 16	8 to 10 A.M.	57	80	— 18 55·9	1·0065	1·0274
Campbelton ...	Sept. 16	6 to 8 P.M.	53	90	— 18 16·1	1·0100	1·0311
Stranraer	Sept. 18	9 to 11 A.M.	52	80	— 19 31·8	1·0026	1·0235
Bangor	Sept. 21	9 to 11 A.M.	50	72	— 18 55·9	1·0059	1·0268
Dublin	Oct. 4	12 to 2 P.M.	49	72	— 19 53·3	1·0000	1·0208

If now we make $f =$ the most probable value of the intensity at the same central geographical position that was assumed in the calculation of the dip observations, viz. lat. 56° 27′, long. 4° 25′ west; $u =$ the angle which the isodynamic line passing through the central position makes with the meridian;

and r = the coefficient which determines the rate of increase of the force in the normal direction; and if we put as before $r \cos u = x$, $r \sin u = y$, and $f = 1 + f'$, we have three series of equations, analogous to those in the dip calculations; each series in the present instance consisting of 23 equations. Summing each series we obtain the three final equations as follows:

$$+ \cdot 7158 = + \ 23 f' - \ 158 x + \ 154 y \quad . \ . \quad (A)$$
$$- 2\cdot 7180 = - 158 f' + 31892 x + 8767 y \quad . \ . \quad (B)$$
$$- \ 1\cdot 251 = + 154 f' + \ 8767 x + 63334 y \quad . \ . \quad (C)$$

From which we obtain by elimination,

$$x = + \cdot 00010705\, ; \ y = - \cdot 00011186\, ;$$
$$u = - 46^\circ \ 15'\cdot 5\, ; \ r = \cdot 0001548\, ; \text{ and } f' = \cdot 0326.$$

The intensity at the central position is consequently 1·0326 to unity in London. The isodynamic line passing through it makes an angle of 46° 15′·5 with the meridian; and lines corresponding to differences of intensity amounting to ·005 are at intervals apart of 32·29 geographical miles. These are the results of the statical method.

II. Intensity.

§ 2. *By the Method of Horizontal Vibrations.*

These observations were made in the well-known apparatus of M. Hansteen. The cylinders employed were two, belonging to Professor Lloyd, which had been extensively used by us both in the Irish magnetical observations, and are described in the report of those observations as L (a) and L (b). The method of observing which I pursued in Scotland is precisely similar to the description given in that Report; and nothing further in respect to it appears necessary to be added here, except that the same silk suspension was preserved throughout; the same chronometer, of small and very steady rate, always employed; and that the coefficient for temperature for both cylinders is ·00025. The column of "corrected time" in the subjoined Tables is the time of vibration reduced by this coefficient to a standard temperature of 60°.

Table V.

Times of Vibration of Cyl. L (*a*).

Station.	Date.	Hour.	Time of Vibration.	Tem.	Corrected Time.	Place of Observation.
		h m	s	°	s	
Dublin	July 24.	9 0 A.M.	243·47	59	243·47	Provost's garden, Trinity College.
	25.	7 30 A.M.	243·11	55		
Helensburgh.	28.	4 40 P.M.	250·90	64·5	251·05	Sea-beach.
	28.	5 10 P.M.	250·93	63·5		
	Aug. 2.	7 16 A.M.	251·33	64·2		
	1.	8 00 A.M.	251·51	55·2	....	Field east of the town.
Gt. Cumbray.	July 30.	1 50 P.M.	249·62	58·2	249·82	Field N.E. end of the island.
	30.	2 10 P.M.	249·79	58		
LochGilphead	Aug. 7.	0 50 P.M.	250·88	69	249·75	Sir John Orde's grounds.
	7.	4 30 P.M.	249·62	61		
	7.	4 50 P.M.	249·30	59		
Tobermorie...	10.	8 20 A.M.	254·79	67	254·34	Sea-beach S. of the town.
Loch Scavig .	12.	6 20 P.M.	263·49	60	263·49	Near the fall from Loch Coruisk.
Loch Slapin...	14.	8 30 A.M.	254·47	59·5	254·50	Inner Loch, E. side, on limestone.
Artornish	16.	8 30 A.M.	252·57	60	252·57	On a limestone point S. of Castle.
Glencoe	17.	8 30 A.M.	250·17	57·5	250·32	Wood near the village.
Fort Augustus	19.	2 50 P.M.	253·40	61	253·34	Field near the fort.
Inverness ...	21.	9 30 A.M.	253·16	52	....	Grounds of Abertorf.
	21.	5 00 P.M.	252·38	53·5	253·11	Craig Phatric.
	21.	5 20 P.M.	252·32	51		
Golspie	23.	8 50 A.M.	253·20	50·5	254·48	Wood near the inn.
	23.	9 20 A.M.	253·15	50·5		
	23.	2 30 P.M.	254·62	52·5		Wood up the glen.
	23.	3 00 P.M.	254·82	53·0		
Inverness ...	24.	0 40 P.M.	253·31	54·0	253·53	Grounds of Abertorf.
	24.	1 10 P.M.	253·07	55·0		
Gordon Castle	25.	1 45 P.M.	252·69	60·0	252·72	Grounds of Gordon Castle.
	25.	2 10 P.M.	252·78	60·5		
Rhynie	26.	6 35 P.M.	250·27	48·5	251·09	Field S.E. of the inn.
	26.	7 10 P.M.	250·42	47·5		
Alford	28.	7 45 A.M.	251·90	54	252·23	Grove, near the manse.
	28.	8 10 A.M.	251·73	52		
	29.	7 50 A.M.	251·79	52·5		
Braemar	30.	9 00 A.M.	250·49	52·5	250·96	Field near the inn.
Blairgowrie...	31.	6 00 P.M.	247·98	57·5	248·10	Field N. of the town.
	31.	6 30 P.M.	247·92	57·5		
Newport	Sept. 1.	1 40 P.M.	251·23	59·5	251·26	A field inland.
Kirkaldy......	3.	9 00 A.M.	250·38	53·5	250·79	Mr. Fergus's garden.
Melrose.	6.	5 50 P.M.	246·91	49·5	247·56	Field E. of the Abbey.
	6.	6 10 P.M.	246·86	48·5		
Dryburgh ...	7.	4 10 P.M.	246·89	55·0	247·20	Tweed side.
Helensburgh .	13.	1 40 P.M.	251·24	61·0	251·27	Field E. of the town.
	14.	12 30 P.M.	251·29	59·0		
Loch Ranza...	16.	10 10 A.M.	252·66	61·5	252·57	Sea-beach E. side of harbour.

TABLE V. (*continued.*)

Station.	Date.	Hour.	Time of Vibration.	Tem.	Corrected Time.	Place of Observation.
		h m	s	°	s	
Campbelton...	Sept. 17.	6 45 A.M.	248·57	48·0	249·33	Sea-beach S. side of the harbour on red sandstone.
	17.	7 00 A.M.	248·61	48·0		
Stranraer......	18.	3 35 P.M.	247·20	54·3	247·68	Field S. of the town.
	18.	3 45 P.M.	247·54	56·0		
Bangor (co. Down) ...	21.	9 45 A.M.	246·53	48·6	247·30	Grounds of Bangor Castle.
	21.	10 15 A.M.	246·72	49·0		
Dublin.........	Oct. 3.	10 10 A.M.	243·25	45·0	243·92	Provost's garden, Trinity College.
	3.	2 8 P.M.	243·22	47·0		
	3.	2 30 P.M.	243·09	48·0		
	4.	1 45 P.M.	243·18	51·5		

Times of Vibration of Cyl. L (*b.*)

Station.	Date.	Hour.	Time of Vibration.	Tem.	Corrected Time.	Place of Observation.
		h m	s	°	s	
Dublin.........	July 24.	8 30 A.M.	293·22	59·0	292·96	Provost's garden, Trinity College.
	25.	8 00 A.M.	292·25	54·0		
	25.	8 40 A.M.	292·57	55·5		
Helensburgh .	28.	4 00 P.M.	302·15	69·4	302·08	Sea-beach.
	Aug. 1.	8 30 A.M.	302·22	54·5		Field E. of the town.
	2.	7 45 A.M.	302·55	65·1		Sea-beach.
Gt. Cumbray .	July 30.	2 30 P.M.	300·53	57·6	300·71	Field N.E. end of the isld.
Loch Gilphead	Aug. 7.	1 25 P.M.	301·73	67·5	300·22	Sir John Orde's grounds.
	7.	5 10 P.M.	298·93	55·5		
Tobermorie...	10.	8 40 A.M.	306·03	67·5	305·46	Sea-beach S. of the town.
Loch Scavig...	12.	8 00 P.M.	316·13	60·0	316·13	Near the fall from Loch Coruisk.
Loch Slapin...	14.	8 50 A.M.	304·97	59·0	305·04	Inner loch on limestone.
Artornish ...	16.	8 50 A.M.	303·75	60·0	303·75	On a limestone point.
Glencoe	17.	9 20 A.M.	300·91	56·5	301·17	Wood near the village.
Fort Augustus	19.	3 00 P.M.	304·30	64·0	304·00	Field near the fort.
Inverness......	21.	8 30 A.M.	302·46	52·0	303·16	Grounds of Abertorf.
	21.	5 30 P.M.	302·42	49·0		Craig Phatric.
Golspie	23.	4 15 P.M.	305·33	53·5	305·87	Wood near the inn.
	23.	4 40 P.M.	305·50	54·0		Wood up the glen.
Inverness ...	24.	11 50 A.M.	303·79	53·0	304·25	Grounds of Abertorf.
	24.	1 20 P.M.	303·68	53·0		
Gordon Castle	25.	1 00 P.M.	303·16	58·5	303·29	In the grounds of the Castle.
	25.	1 20 P.M.	303·27	59·5		
Rhynie	26.	6 10 P.M.	300·27	50·5	301·24	Field S.E. of the inn.
	26.	7 25 P.M.	300·34	44·5		
Alford	28.	8 30 A.M.	302·04	52·	302·67	Grove near the manse.
	28.	8 50 A.M.	302·09	52·		
Braemar	30.	9 30 A.M.	300·47	54·5	300·88	Field near the inn.
Blairgowrie...	31.	5 20 P.M.	297·47	57·5	297·69	Field N. of the town.
	31.	6 45 P.M.	297·47	56·4		
Newport	Sept. 1.	1 00 P.M.	301·79	61·0	301·72	A field inland.
Kirkaldy......	3.	10 30 A.M.	300·80	59·0	300·87	Mr. Fergus's garden.

TABLE V. (*continued.*)

Station.	Date.	Hour.	Time of Vibration.	Tem.	Corrected Time.	Place of Observation.
		h m	s	°	s	
Melrose	Sept. 6.	6 40 P.M.	295·68	46·5	296·85	Field E. of the Abbey.
	7.	8 45 A.M.	296·55	53·5		
Helensburgh .	13.	2 10 P.M.	301·61	61·5	301·33	Field E. of the town.
	14.	11 45 A.M.	300·99	57·0		
	14.	12 05 P.M.	301·23	59·0		
Loch Ranza . .	16.	9 30 A.M.	302·76	58·0	303·15	Sea-beach.
	16.	9 50 A.M.	303·39	60·0		
Campbelton...	17.	7 20 A.M.	298·30	50·0	299·05	Sea-beach; on red sandstone
Stranraer......	18.	2 40 P.M.	297·03	56·4	297·06	Field S. of the town.
	18.	3 10 P.M.	296·42	54·4		
Bangor	Sept. 21.	11 10 A.M.	295·28	49·6	296·04	Grounds of the Castle.
Dublin.........	Oct. 3.	9 25 A.M.	291·02	44·5	292·21	Provost's garden, Trinity College.
	3.	9 45 A.M.	291·24	44·5		
	3.	2 55 P.M.	291·37	49·6		
	4.	1 15 P.M.	291·73	53·5		

From the near agreement in the respective times of vibration of the cylinders in Dublin in July and in October, we may infer that the magnetic state of each cylinder had experienced little, if any, alteration in the interval; an inference which is also confirmed for a portion of the interval by the correspondence in the times of vibration at Helensburgh in July and September. The times of vibration in Dublin at the two periods referred to are as follows, viz.

	Cyl. L (*a*).	Cyl. L (*b*).
	s	s
July 24 and 25............	243·47	292·96
October 3 and 4..........	243·92	292·21

Whence it would appear, if we ought to draw any conclusion from such small differences, that Cyl. L. (*a*) had sustained a small decrease of magnetism in the interval, and Cyl. L (*b*), on the contrary, a small increase, and very nearly to a proportionate amount. However this may be, we cannot err materially in regarding the mean of the times of vibration of each cylinder in July and October, as its rate in Dublin comparable with the rates observed at the different stations in Scotland. The following Table has been computed accordingly. The first of the three columns under the general head of "Horizontal Intensity," expresses the ratio of the horizontal force at each station to unity in Dublin, deduced from the times of vibration of Cyl. L (*a*); the next column the ratios deduced from Cyl. L (*b*); and the third column contains the ratios deduced from a mean

of the two cylinders. The first column, under the general head of "Total Intensity," shows the ratios of the total force derived from the mean horizontal component by the formula $f = \frac{h \sec \delta}{h' \sec \delta'}$; δ' and h' being the dip and horizontal intensity in Dublin, and δ and h the same quantities at another station. The final column contains the values in the preceding column multiplied by 1·0208.

Table VI.

Magnetic Intensity deduced by the Horizontal Cylinders.

Station.	Horizontal Intensity.			Observed Dip.	Total Intensity.	
	Cyl. L. (a).	Cyl. L. (b).	Mean.		Dublin=1.	London=1
Dublin	1·0000	1·0000	1·0000	70 59·4	1·0000	1·0208
Helensburgh..	0·9422	0·9381	0·9402	72 14·2	1·0038	1·0247
Cambray	0·9516	0·9467	0·9491	71 58·7	0·9992	1·0200
Loch Gilphead	0·9521	0·9498	0·9510	72 05·2	1·0071	1·0280
Tobermorie ..	0·9180	0·9175	0·9178	73 05·2	1·0276	1·0490
Loch Slapin ..	0·9169	0·9200	0·9184	72 59·7	1·0229	1·0442
Artornish	0·9309	0·9278	0·9293	72 40·4	1·0164	1·0375
Glencoe	0·9478	0·9438	0·9458	72 14·7	1·0103	1·0313
Fort Augustus	0·9253	0·9263	0·9258	72 37·9	1·0102	1·0312
Inverness	0·9270	0·9314	0·9292	72 44·0	1·0197	1·0409
Golspie	0·9170	0·9150	0·9160	72 53·1	1·0138	1·0349
Inverness	0·9239	0·9248	0·9244	72 44·0	1·0144	1·0355
Gordon Castle	0·9299	0·9306	0·9302	72 38·4	1·0155	1·0366
Rhynie	0·9420	0·9434	0·9427	72 23·2	1·0148	1·0359
Alford	0·9335	0·9345	0·9340	72 19·5	1·0020	1·0228
Braemar	0·9429	0·9456	0·9442	72 11·7	1·0058	1·0267
Blairgowrie ..	0·9648	0·9660	0·9654	71 52·2	1·0105	1·0315
Newport	0·9409	0·9402	0·9406	72 14·9	1·0049	1·0258
Kirkaldy	0·9420	0·9457	0·9439	72 08·5	1·0026	1·0234
Melrose	0·9690	0·9715	0·9702	71 34·4	0·9997	1·0205
Dryburgh	0·9719	......	0·9719	71 31·2	0·9987	1·0195
Helensburgh..	0·9406	0·9430	0·9418	72 14·2	1·0055	1·0264
Loch Ranza ..	0·9310	0·9316	0·9313	72 20·4	1·0002	1·0210
Cambelton ..	0·9553	0·9574	0·9563	71 53·5	1·0022	1·0230
Stranraer	0·9681	0·9701	0·9691	71 40·9	1·0043	1·0252
Bangor	0·9710	0·9768	0·9739	71 36·9	1·0058	1·0267
Dublin	1·0000	1·0000	1·0000	70 59·4	1·0000	1·0208

The observed dips in Table VI. are the same as those in Table I. with the exception of the dip in Dublin, at which station I have availed myself, in addition to my own observations, of the numerous results which Mr. Lloyd has obtained with several dipping needles at the same spot where the cylinders were vibrated. An abstract of all these observations from which the dip in

Dublin is derived for the month of September 1836, is given in the subjoined Table.

Date.	Needle.	Dip observed.	Reduced to Sept. 1836.	Mean.
Sept. 1834.	I.	71 03·8		
Sept. 1834.	IV.	71 05·1		
Mean	……	71 04·1	=70 58·3 (16 obs.)	70° 59′·4, allowing weight to each result, proportioned to the number of observations
Sept. 1835.	I.	71 03·5		
Sept. 1835.	IV.	71 02·0		
Mean	……	71 03·0	=71 00·0 (18 obs.)	
Nov. 1835.	IV.	71 01·3	=70 58·8 (3 obs.)	
April 1836.	IV.	71 02·1		
April 1836.	III.	70 59·5		
Mean	…….	71 00·8	=70 59·8 (8 obs.)	
July 1836.	S (2)	71 01·12		
Oct. 1836.	S (2)	71 00·75		
Mean	………	71 00·93	=71 00·9 (4 obs.)	

In Table VI. we have twenty-five results to be combined by the method of least squares, in order to determine the most probable values of f', x, and y. The equations are analogous to those already described in treating of the statical results. We obtain from them the three final equations

$$+\ \cdot 7422 = +25 f' - 73 x + 11 y \qquad \text{(A.)}$$
$$+\ \cdot 1816 = -73 f' + 35681 x + 13117 y \qquad \text{(B.)}$$
$$-\ 5\cdot 9458 = +11 f' + 13117 x + 66193 y \qquad \text{(C.)}$$

From which we find by elimination

$$x = +\cdot 0001094 \qquad y = -\cdot 0001165$$
$$u = -46^\circ\, 47\cdot 5;\ r = \cdot 0001598;\ \text{and}\ f' = \cdot 0301.$$

The intensity at the central position (lat. 56° 27′, long. 4° 25′ W.) is consequently 1·0301 to unity in London. The isodynamic line passing through it makes an angle of 46° 47′·5 with the meridian; and the isodynamic lines corresponding to differences of intensity amounting to ·005 are at intervals apart of 31·28 geographical miles.

By the statical method we have found the intensity at the central station 1·0326; the angle with the meridian made by the isodynamic line 46° 15′·5; and the intervals between isodynamic lines representing differences of intensity of ·005, to be 32·29 geographical miles.

The agreement of the two methods cannot be considered otherwise than as very remarkable. They have no element in common except the dip, which, whilst it is very influential in the horizontal method, might be many minutes in error without sensibly affecting the results by the statical method. The close agreement of two methods, which are thus independent of each other, forms a strong mutual corroboration.

By substituting in the original equations the values thus found of f', x, and y, we may compute the intensity assigned by the combination of the observations at all the stations to the geographical position of each station in particular, and we shall thus see what degree of accordance the observations at each station exhibit, with the indications of the combined results. The following table shows the differences between the observed and the combined result at each station by both the horizontal and statical methods; the sign + signifies that the observed intensity is in excess; − that it is in defect.

Table VII.

Differences of Observed and Computed Results.

Station.	Horizontal.	Statical.	Station.	Horizontal.	Statical.
Loch Slapin ...	+·0029	+·0007	Helensburgh ...	−·0025	−·0034
Golspie	−·0042	−·0039	Campbelton ...	−·0043	+·0011
Tobermorie ...	+·0118	+·0080	Cumbray	−·0071	+·0004
Inverness	+·0020	+·0012	Glasgow	......	−·0033
Artornish	+·0017	......	Newport	+·0014	+·0020
Fort Augustus .	−·0045	......	Kirkaldy	+·0002	+·0033
Glencoe	−·0027	−·0027	Blairgowrie......	+·0044	+·0065
Gordon Castle...	+·0033	+·0033	Bangor	+·0044	+·0014
Loch Gilphead .	−·0032	......	Edinburgh	......	−·0004
Rhynie	+·0052	......	Stranraer	+·0036	−·0010
Braemer	−·0037	−·0048	Melrose	+·0027	+·0015
Alford............	−·0068	−·0013	Dryburgh	+·0021	+·0008
Ranza............	−·0070	−·0033			

We have seen that each of the two methods gives, when taken separately, general results agreeing in a very remarkable manner with those of the other method. When however we examine the contents of the preceding table, we remark that in the horizontal method much greater differences appear between the observed and the combined results at single stations, than is

the case in the statical method. This accords with the anticipations of the inventor of the statical method. And when it is considered that an error of a single minute in the observation of the dip will occasion, in so high a magnetic latitude as Scotland, a corresponding error of ·0009 in the deduction of the total intensity from the horizontal vibrations, it must be acknowledged that the statical method possesses a great advantage in such latitudes, in being free from this source of liability to error. I must add, however, that I do not attribute the discrepancies observable in the results of the horizontal method, beyond those of the statical, altogether to defects inherent in the horizontal method. The necessity of economizing time obliged me frequently to keep the dipping needle and the horizontal cylinders employed at the same time, when it was of course necessary to place them several yards apart. In a country so subject to local magnetic disturbance as Scotland, it is not too much to say, that it might not always follow that the dip should have been precisely the same at the two spots of observation. I have already noticed that at the two sides of the harbour at Loch Scavig I observed a difference of above 5° of dip; and although that was no doubt an extreme case and one of very rare occurrence, it can scarcely be supposed but that irregularities do occur in a minor degree not unfrequently. In strict justice to the horizontal method, the cylinders, in countries liable to such local influences, should always be vibrated precisely in the same spot where the dip is observed. The place of observation of the two methods not being the same, may also subject the instruments to actual differences of *intensity* apart from the magnetic *direction*. In such cases the results may be true measures, though differing from each other; but discrepancies of this nature should not exceed the limit of the local irregularities of intensity, the existence of which we may infer from the statical results. When they are considerably greater, a more probable mode of accounting for them is that the horizontal needle was affected by a different dip from that acting on the dipping needle and used in the reduction. In all such cases the total intensities derived from the horizontal vibrations are of course in error. It has been shown by the corresponding table of the dip observations that there were seven stations at which the observed dip differed from the dip computed by a combination of the observations at all the stations to an amount varying from 14′·5 to 25′·1. At six of these stations there were also horizontal and statical observations of the force. Had the differences between the observed and computed dips in these cases been errors of observation, and not actual irregularities in the magnetic direc-

tion from some disturbing cause, the discrepancies between the two methods of measuring the force must have been far greater than they are. The error in the deduction of the force by the horizontal method which would be occasioned by an error of observation of 14′ of dip, would have greatly exceeded any discrepancy existing between the horizontal and statical results in the above table. Considerations of this kind are important in their bearing on the proper method of deducing the lines of total intensity from a series of horizontal vibrations. If discrepancies in the observations of dip arise chiefly from instrumental errors or errors of observation, the dip resulting from the calculation of least squares should be used in the reduction of the horizontal observations. If, on the other hand, the probability of local disturbance is greater than of instrumental error, the dips actually observed should be employed in the reduction. Were the dips due to the geographical positions employed in the reduction of the Scottish observations instead of the dips actually observed at the stations, the discrepancies in the resulting intensities would be increased to such an extreme amount, as to leave no doubt that, in the case of the Scottish observations at least, the observed dips are those which ought to be employed; and it also follows, that in countries subject to such magnetic irregularities, the dipping-needle should be regarded as an indispensable accompaniment to the horizontal cylinders.

All the observations made with the statical needle have been included in the calculations, as well as all those with the horizontal cylinders, except the vibrations at Loch Scavig, which were evidently affected by some very great cause of irregularity, and their introduction into the calculation could only be productive of error. Loch Scavig, with its hypersthene rocks and its trap dykes, is evidently a very unsuitable place for magnetic observations.

The general results from the statical and horizontal methods are so nearly the same, that either might be used for the chart with scarcely a perceptible difference. Perhaps the statical results may be considered as entitled to a preference, and they have been employed accordingly.

Until the relation which the isodynamic lines in Scotland bear to the magnetic intensity in England shall be more thoroughly and satisfactorily ascertained, by a connected series of observations comprehending the whole of Great Britain, it has been deemed preferable to give the Scottish lines no other designation in the chart than that which expresses their relation to each other, thus limiting the conclusion to what is strictly war-

ranted by the observations recorded in this paper. Accordingly, the line passing through the central station, and making with its meridian an angle of 46° 15′·5, is designated simply as unity for Scotland; and the other lines, at intervals of 32·29 geographical miles, are entitled +·015, +·010, +·005, −·005, −·010, −·015, according to the values of the intensity which they represent relatively to the central line.

The difference between the deductions in Ireland and in Scotland, in regard to the isodynamic lines, is considerable, and apparently too great to be supposed due to an actual difference in the lines themselves. It will probably be elucidated by future observations.

Report on North American Zoology. By JOHN RICHARDSON, *M.D., F.R.S., &c.*

THE following paper having reference to the animals of only a single zoological province, bears the same relation to the valuable report made to the Association by the Rev. Leonard Jenyns, "On the present State of Zoology*," that *a local fauna* does to a work embracing the whole *animal kingdom*. As it leaves untouched the principles of systematic arrangement, structure, physiology, and in fact the fundamental doctrines of the science, the only subjects coming properly within its scope appear to be, *an enumeration of the animals inhabiting North America;* the *peculiarities of the fauna which they constitute* when contrasted with those of the other zoological provinces into which the earth may be divided; and *the geographical range of groups or individual species*, with the circumstances which tend to influence its extent, such as the *configuration of the land, climate, vegetation, &c.* The only author who has written on the latter branch of the subject is Mr. Swainson, to whom we are indebted for an enumeration of the generic forms peculiar to North America †. No separate treatise has hitherto been devoted to the laws which regulate the distribution of animals in North America, and the geographical limits of each species have been very imperfectly pointed out in the systematic works containing descriptions of the animals. Hence, as the reports called for by the British Association are designed to exhibit the present state of science, and not for the publication of new facts or the mere enunciation of the reporter's opinions, portions only of the outline of a complete fauna will be traced in the following sketch; but the purpose of the report will be answered if it serves to point out the gaps in North American zoology which require to be filled up, and to direct the attention of travellers and resident naturalists to those investigations which are im-

* Vide *Report of the Fourth Meeting*, &c. London, 1835, p. 143. Mr. Jenyns limits his report to "those researches which of late years have tended to elucidate the characters and affinities of the larger groups of animals, and thereby to advance our knowledge of their natural arrangement." The great extent of the field of inquiry thus marked out will appear by a quotation from the first zoologist of the age: "*En un mot, la méthode naturelle serait toute la science, et chaque pas qu'on lui fait faire approche la science de son but.*" (Cuv., *Reg. An.*, i. 10.)

† Published in the *Encyclopædia of Geography*; and in his volume on the *Geography and Classification of Animals*, forming part of *Lardner's Cyclopædia.*

portant to the interests of science. A correct knowledge of the species is clearly the first point to be attained, being indispensable for the due discussion of the other subjects embraced by a local fauna; but though this has formed the chief aim of the works hitherto devoted to North American zoology, great uncertainty still exists as to many species, the original descriptions being so obscure that they do not enable us to recognise the animals ; and even the commonest quadrupeds, about whose identity, when found in certain localities, there can be no doubt, have in very few instances, indeed, been satisfactorily compared with the analogous ones inhabiting distant districts of America or belonging to the old world. A critical review of the various opinions entertained by zoologists respecting the several species, (such as that which the Prince of Musignano has instituted in his observations on Wilson's *Ornithology*,) would be obviously of great utility, but want of space excludes it from this report, wherein the *Mammalia* alone will be noticed in detail. The preference is given to this order, partly because, the number of species being small, individual notices can be compressed within reasonable limits, but chiefly because opinions are more various concerning the quadrupeds than respecting the contents of the other orders. A sketch of the labours of the different authors who have brought North American zoology to its present state might have been introduced, but its utility would not compensate for the space it would occupy, and the task has been already to a certain extent executed in the introductions to the several volumes of the *Fauna Boreali-Americana*. The reader is therefore referred to that work, to the *American Natural History* of Dr. Godman, the *Fauna Americana* of Dr. Harlan, and especially to Pennant's *Arctic Zoology*, which contains ample references to all the older writers. Fischer's *Synopsis Mammalium* is a good book of reference for the published species of *Mammalia* up to the year 1828.

Previous to entering upon the details of the report, it is necessary to state that in it the term of North America is restricted to that part of the continent which lies north of the tropic of Cancer, thus including New Mexico, the Peninsulas of Florida and California, and as nearly as may be meeting the limits of the very different and peculiar South American zoological province. In considering Mexico as the region in which the Northern and Southern American faunæ meet and mingle, I follow the opinions of Professor Lichtenstein* and Mr. Swain-

* "Erläuterungen der Nachrichten des Franc. Hernandez von den vierfüssigen Thieren Neuspaniens, von Herr Lichtenstein." Gelesen in der Akademie der Wissenschaften am 28 Jun. 1827. Berlin.

son *, and dissent from those who consider the Isthmus of Darien as a zoological boundary †.

Physical Geography.

The great range of the Rocky Mountains forms a most remarkable feature in the physical aspect of North America. Viewed as a continuation of the Cordilleras de los Andes of the southern continent, and extending from the Straits of Magalhães to the Arctic sea through 120° of latitude, it is by far the longest mountain chain in the world. In Mexico it divides into three branches; the western one passing through the province of Guadalaxara to the Rio Gila; the eastern one extending through the Texas towards the confluence of the Missouri and Mississippi, where it terminates after assuming the appellation of the Ozark Mountains; and the highest or central branch continuing northwards to between the 29th and 30th parallels of latitude, where it is linked to the lateral forks by connecting spurs, or as Humboldt names them "counter forts." Within this mountain system, between the parallels of 19° and 24½°, lie immense *table lands*, elevated to the height of 6000 or 7000 feet above the sea. The central Cordillera of Mexico has a direction of N. 10° W. from the 25th to the 38th degree of latitude; and from thence the course of the ridge is with very slight deflections about N. 28° W. to the 69th parallel and 138th meridian, near the mouth of the Mackenzie, where the Rocky Mountains terminate. Travellers, who have crossed the mountains at various parts, inform us that they are divided into several parallel ridges; this is the case near the sources of the Rio del Norte; again between the 37th and 41st parallels; in the 58th parallel; and lastly, in the 64th, where according to the report of the fur-hunters thirteen successive ridges must be crossed before the western declivity is attained. Many of the peaks of the Rocky Mountains rise to a considerable altitude: thus, Spanish Peak, lat. 37° 20′ N.; James Peak, 38° 38′; and Bighorn, lat. 40°, have been ascertained by officers of the United States to be from 10,000 to 12,000 feet in height. Mount Hooker and Mount Brown, in the 52nd and 53rd parallels, were stated by the late Mr. Douglas, but from less perfect data, to be respectively 15,690 and 15,900 feet above the sea. It is manifest that animals may travel along the acclivities of a mountain chain whose summits enter within the limits of perpetual snow, from the

* *Encyclopædia of Geography*, 1834; *Geography and Classification of Animals*, by William Swainson, Esq., 1835.

† *Penny Cyclopædia*, art. AMERICA.

arctic circle down to the table lands of Mexico, almost without varying their climate; and that were the altitude of the ridge between the tropics great enough and sufficiently continuous to join the temperate zones of North and South America, we might expect to find many species of quadrupeds and birds common to both; but it so happens that in the Isthmus of Panama, nearly at the place where the elevation for the accomplishment of such an union would require to be greatest, the Cordilleras are depressed to a height not exceeding 500 or 600 feet, and still further south there is a plain extending from sea to sea between Rio Naipipi and the Gulf of Cupica*. It is not, however, as Humboldt has remarked, the altitude of the mere peaks which is to form an element in an inquiry of this kind, but rather the heights of the backs of the mountains over which the passes from one side of the chain to the other are usually made. But we have no positive information respecting the height of the passes of the Rocky Mountains, and even the altitude of the base of the range above the sea, which forms a material item in the computation of the absolute elevation of the peaks, has not been calculated from barometric measurement, but merely by vague estimates of the descent of rivers. Major Long assigns to this base a height of 3000 feet, while Lieutenant Pike with less probability more than doubles that altitude.

The Rocky Mountains are bounded on the Atlantic side by vast plains, having a gradual inclination to the eastward, and forming, from the 50th degree of latitude down to the Gulf of Mexico, a water-shed traversed by the Red River, the Arkansas, Missouri, and Mississippi. A zone to the westward of the latter river about 200 miles broad is well wooded, but the remainder consists of sandy and naked prairies, whose surface though gently undulated presents as few landmarks to guide the traveller on his way as he would meet with in the middle of the ocean†.

Between the 50th and 54th parallel lie plains of similar character, crossed by the forks of the Saskatchewan, which falls into Hudson's Bay; and still further north the Peace River flows towards the Arctic sea through a fertile tract generally level, and inclosing portions of prairie land, but more encroached on by pine forests than the southern plains. The valley of the Mackenzie beyond the 61st parallel, instead of being separated from the Rocky Mountains by an intervening level tract of land, skirts their bases until it issues in the Arctic sea. We thus perceive that to the eastward of the Rocky Moun-

* Humboldt.

† The eastern banks of the Mississippi are in general thickly wooded, but in the State of Illinois there are some considerable tracts of prairie lands.

tains there is an immense longitudinal valley extending from the Arctic sea to the Gulf of Mexico, crossed by no dividing ridges of note, but forming three separate water-sheds; the southerly one having, in addition to a general easterly declination to the Mississippi, also a descent from the 49th parallel towards the outlet of the latter river in the Gulf of Mexico; the northerly one having an inclination towards the Arctic sea, commencing between the 53rd and 54th degrees of latitude and the central one, which is necessarily the most elevated, having merely an easterly descent towards Hudson's Bay. The valley or plain is widest beween the 40th and 50th parallels, where it includes 15 degrees of longitude. This configuration of the land evidently gives great facilities for the range of herbivorous quadrupeds from north to south, and is the line of route pursued by many species of migratory birds; and while the Mackenzie furnishes a channel by which the anadromous fish of the Arctic sea can penetrate 10 degrees of latitude to the southward, the Mississippi offers a route by which those of the Gulf of Mexico can ascend far to the north.

There are no mountain chains to the eastward of the Mississippi at all approaching to the Rocky Mountains in magnitude, the most remarkable of the existing ones being the Alleghanies or Apalachian ranges, which have a breadth of about one hundred miles, and rise from 2000 to 3000 feet above the sea, springing from a base elevated 1000 or 1200 feet. They extend from Alabama and the northern confines of Georgia nearly to the banks of the St. Lawrence, their general direction being about N.E. by N., that is, nearly parallel to a line drawn from Carolina to Nova Scotia through the principal promontories of the Atlantic coast, and forming an angle of five points with the Rocky Mountain chain. The strip of country intercepted between the Alleghanies and the Atlantic, undulating and rising moderately towards the base of the mountains and generally very level near the coast, has a width of 200 miles in the Carolinas. In Georgia the low land becomes broader, and sweeping to the westward round the south end of the chain it joins the valley of the Mississippi. To the southward the level is continued into the peninsula of Florida, and this tongue of land must be noticed as influencing the distribution of animal life, not only by its southerly extension, amounting to five degrees of latitude, but also by its forming a barrier to the direct passage of fish from the Atlantic coast to the same parallel in the bottom of the Gulf of Mexico, and thus partly accounting for the very peculiar ichthyology of the Mississippi and its tributaries as contrasted with that of the eastern rivers.

The whole northern shore of the Gulf of Mexico is low and swampy, and from the very gradual shoaling of the water, inapproachable by ships, except at the mouths of rivers. The coast preserves much the same character on the Atlantic side up to Virginia, being almost everywhere skirted by low sandy islands, inclosing extensive lagoons and winding channels, into which numerous large rivers open, and permit the access of anadromous fish to the foot of Alleghanies. In the middle and eastern districts of the United States the Atlantic plain is narrowed by an incurvature of the coast and the extensive encroachments of the Chesapeake, Delaware, and Long Island Sounds, to whose muddy beaches vast numbers of water-fowl resort. A narrow valley, having a direction of N. by E., runs from the last-mentioned sound to join the transverse basin of the St. Lawrence: it is occupied on one side by the River Hudson and on the other by Lake Champlain and the River Richelieu*.

The British Atlantic territory is also deeply indented by the Bay of Fundy, remarkable for the rise of its tides, and the extent of its mud banks exposed at low water. The island of Newfoundland, viewed merely in reference to its physical geography, appears as a prolongation of the coast line; in its animal productions and vegetation it corresponds with the adjacent coast of Labrador. Its surface, as well as that of New Brunswick, Nova Scotia, and the northern part of the United States, is considerably varied by hills.

We have next to notice a great transverse valley, commencing with the mediterranean sea or gulf of the St. Lawrence, continued first to the south-westward behind the Alleghanies in the channel of the river St. Lawrence and basins of Lakes Erie and Ontario, and afterwards more directly to the west by the valleys of Lakes Huron, Michigan, and Superior, from the two latter of which there are communications by low tracts of land with the great basin of the Mississippi. Canals have been executed and more are projected in the Canadas and United States for connecting the several systems of water communication, by means of which an interchange of fish from widely diverging rivers will hereafter take place.

The interior prairie lands lying to the northward of the great Canada lakes have on their eastern boundary a well-wooded, but swampy zone of nearly level limestone strata analogous to the valley of the Mississippi in its general direction, and having on or near its eastern border an almost continuous water-course,

* A recent traveller states that the only instances of tidal waters of sufficient depth to carry large ships crossing primitive mountain chains, are those of the Hudson and St. Lawrence. *Vide* Stuart's *Three Years in America*.

which may be traced on the map as the River and Lake Winipeg, lower part of the Saskatchewan, Beaver Lake, Mississippi, Athabascow River and Lake, Slave River and Great Slave Lake, from whence Mackenzie's River issuing sweeps round the north end of the zone, and approaches the base of the Rocky Mountains within the Arctic circle. This longitudinal water-course lying nearly at a right angle with the transverse valley of the St. Lawrence cuts off a large north-east corner of the continent, including the Canadas, Labrador, Rupert's Land, and the more northern districts. Though this tract, which equals Europe in extent, has a greatly varied surface and includes some high groups of hills, it possesses no continuous mountain ranges of great elevation, nor indeed any peaks which reach the limits of perpetual snow. Its lakes are numerous and often large, the proportion of water to land being great. In a zoological point of view the district admits of being divided into two portions: the northern one, destitute of trees and therefore named the "barren grounds," lies beyond a line running W.N.W. from Hudson's Bay in the 60th parallel to Great Bear Lake in the 65th. The southerly portion is wooded, and although it embraces many degrees of latitude it presents a surprising uniformity everywhere in its ferine inhabitants. The great inland sea of Hudson's Bay, occupying the centre of the whole north-east district, (the lands north of Hudson's Strait being considered as part of it,) materially influences its temperature, and consequently its capability of supporting animal life. The south and south-west shores of this bay are flat and swampy with muddy beaches, whereon vast flocks of water-fowl halt for a time in the course of their autumn migrations from the northern breeding-places to their southerly winter haunts.

On the Pacific side of the Rocky Mountains we have to the northward an expanded wing, as it were, of the continent prolonged by the peninsula of Alaska and the Aleutian Islands, and similar in geological and zoological characters, as far as has been ascertained, to the eastern barren grounds. Further to the south the coast line approaches the Rocky Mountains, but it recedes again in Upper California; while Lower or old California runs out in a peninsular form like Florida, intercepting the Gulf of Cortes or the Vermilion Sea, which though much narrower than the Gulf of Mexico extends nearly as far northwards. The Pacific coast is flanked at some distance by a range termed by Humboldt the "*Californian Maritime Alps*".

These are in general nearly parallel to the Rocky Mountains, and become more and more elevated as they proceed northwards

from the comparatively low peninsula of California until they attain an elevation of 9000 feet opposite Cape Mendocino in the 40th degree of latitude. Near the 45th parallel, Mount Hood* rises 16,000 feet, and in the 46th stands Mount St. Helens, which is 14,000 feet high; the Columbia flows between these lofty peaks. Mount Fairweather in latitude 59° has an altitude of 14,000 feet, and Mount St. Elias in the 60th parallel attains to 17,000. These peaks are volcanic, and in the Aleutian Islands there is another volcanic mountain 7000 feet high. The Californian Alps are divided into ridges by long narrow valleys, and between them and the Rocky Mountains lies an extensive prairie tract, 700 miles long, from 100 to 200 wide, destitute of water, and very similar in character to those which lie on the eastern side of the ridge just named†. Between the forks of the Columbia there are also wide prairie lands covered with *artemisiæ*, and nourishing several interesting and large species of *tetrao*.

The mountain system of Russian America is unknown. The peninsula of Alaska and the Aleutian Isles, extending towards Asia, separate from the Pacific the sea of Kamtschatka, which nourishes several fish of very peculiar forms and some singular cetaceous animals.

Climate.

Many precise and long-continued meteorological observations are required to be made in various districts of North America before a general view of the climate having any pretensions to accuracy can be offered. Abstracts of temperatures already recorded are expressed in the subjoined table, which is constructed after a model furnished by Humboldt. It is preceded by a few remarks, which are either simply explanatory, or which detail facts not readily expressible in a tabular form, yet of importance to the naturalist who investigates the distribution of animals in North America.

* Dr. Gairdner, an excellent naturalist now employed in a medical capacity on the banks of the Columbia by the Hudson's Bay Company, has executed a map, from which I have extracted the following positions of the most remarkable peaks of the Californian Alps that have received names. Mount Pit, 41° 36′ N.; Mount Shasty, 43° 16′ N.; Mount Vancouver, 44° 18′ N.; Mount Hood, 45° 16′ N.; Mount St. Helens, 46° 05′ N.; Mount Rainier, 46° 57′ N.; and Mount Baker, 48° 27′ N.

† Dr. Coulter states that the Californian Alps form an union with the Rocky Mountains north of the 42nd parallel, about the summit level dividing the head-waters of the Columbia from those which fall into the Bay of St. Francisco. (*Geogr. Tr.*, v. 68.) The "counterfort" here alluded to, hems in the Snake River or south branch of Columbia and limits the range of the bison westwards. The difficulty of traversing this connecting ridge is well described by Washington Irving in his recent work of Astoria.

Writers on climate have remarked that the eastern coasts of continents in the northern hemisphere have a lower mean temperature than the western coasts. This is certainly true in the higher latitudes of North America, for the winters are much milder and the vegetation more luxuriant to the westward of the Rocky Mountains *. On the coast of Hudson's Bay down to the 56th parallel the subsoil is perpetually frozen, and further inland in the 50th degree of latitude the mean annual heat is only 36° F. and the ground is covered with snow for more than six months in the year. Even in the 45th parallel on the north side of the Canada lakes the frost is continuous for more than six months, and the grallatorial and most of the granivorous birds can find no means of support during the winter season; consequently the migration of the feathered tribes is much more general than in the countries of Europe lying under the same parallels. Occasional frosts occur as low down on the Atlantic coast as the confines of Florida, where during the late war several British soldiers were severely frostbitten; this was near the 30th parallel, or that of Morocco, Cairo, and Suez. In Mexico and Old California there are also sharp frosts even on the low grounds, from local causes. The severity of the winters in the 40th parallel and even lower on the Atlantic coast of North America destroys many evergreens which flourish all the year in Scotland, 18 degrees further north.

The decrement of mean annual heat on an increase of latitude is greater in North America than in Europe, and in the former country there is a wider difference between the summer and winter temperatures; that is, the isothæral lines in their passage through America curve convexly towards the pole and the isocheimal lines towards the equator.

Vegetation (the growth of forests in particular) is more influenced by the amount and duration of heat than by the severity of the winter cold. In countries whose mean heat is below 63°, spring, or the renewal of vegetation, takes place, as Humboldt has shown, in that month which attains a mean temperature of 33° or 34°; and deciduous trees push out their leaves when the mean rises to 52°. It follows from this that the sum of the temperatures of the months which attain the latter heat furnish a measure of the strength and continuance of vegetation. On the eastern coast at Winter Island, lying in latitude $64\frac{1}{4}$°, no month of the year reaches a mean heat of 52°; but in the in-

* Geologists may find it worth while to inquire how far the superior climate of the Pacific coast is influenced by the active volcanos of the maritime Alps. No recent volcanos exist in the Rocky Mountains or more eastern ranges.

terior at Fort Enterprise and Fort Franklin, in $64\frac{1}{2}°$ and 65°, there are two such months. In latitude 45° near the middle of the continent there are five, in latitude 35° there are nine, and towards the southern extremity of Louisiana, in $29\frac{1}{2}°$ N. lat., there are eleven; while within the tropics the trees are evergreen.

The gradual ascent of the isothæral lines as they recede from Hudson's Bay is shown by the direction of the northern termination of the woods. On the coast near Churchill trees cease about the 60th parallel; but at the distance of sixty miles from the sea their boundary line rises rapidly, and then takes nearly a straight W.N.W. course, until it reaches Great Bear Lake, in latitude 65°: still further west on the banks of the Mackenzie the woods run to 68° N. lat. We do not know the course of the line of termination of the woods in the interior of Russian America. In the elevated lands of New Caledonia the snow is said to be very deep in winter, and to cause a great scarcity of the larger ruminating animals; but near the mouth of the Columbia there are almost constant rains during that season, with little frost or snow. There are some peculiarities in the climate of Lower California and the adjoining parts of Mexico, which are mentioned in the subjoined note*.

In the high latitudes of North America, at some distance from the coast, the intense colds of winter have a very considerable, though indirect influence on the summer vegetation, and consequently on the capabilities of the country for maintaining animal life: for independent of the accumulation of

* In a paper by Dr. Coulter, published in the 5th vol. of the *Transactions of the Geographical Society*, the following remarks on the climate of Mexico and California occur:—"The mercury in a thermometer shaded from the sun, but within the influence of radiation from an arid plain, frequently stood at 140° F., but this great heat was owing to temporary and local causes. The surface of the country, composed of bare mountains or arid plains completely destitute of water, does not mitigate the cold winds blowing from the Rocky Mountains lying to the north and north-east; hence when they blow for any length of time it freezes even to the south of Pitis, in latitude 29° N., and in the winter of 1829-30 it froze at that place every night for nearly two months. On the table land of Mexico similar cases of cold occur more frequently, as may be easily conceived from their greater elevation and the same general scarcity of water. At Veta Grande, Zatatecas, during the month of December, 1825, it frequently froze hard. The condition of the countries on the confines of Sonora and California is peculiar, as lying between the summer and winter rains. The whole rain of Mexico may be said to fall in the summer months, but in Upper California it rains only in the winter. The summer rains reach the lower part of Sonora, where they are scanty and irregular, and from Pitis northwards across the sands it rarely rains at all; as is also the case in the northern portions of Lower California, where the summer rains scarcely prevail to the northward of Loretto, the capital." (*Lib. cit.*, p. 70.)

irritability which may be supposed to take place in trees and other plants during their long and complete hybernation, an increased effect is given to the sun's radiation by the clearness of the atmosphere, brought about in the following manner. During the intense winter colds, which are very seldom interrupted by a rise of the temperature to the thawing point, the solvent power of the air is so much diminished that almost all the moisture is deposited in the form of snow*; but in spring it is increased by the heating action of a sun that never sets, while the ice-covered lakes, bearing so large a proportion to the land in America, supply it with moisture slowly. The consequence is unusual clearness of the atmosphere, enabling the rays of the sun to produce their full effect. On the confines of the arctic circle an agreeable warmth is often perceived in the sunshine during the months of April and May, when the temperature of the air in the shade is below zero. But for this adaptation of the constitution of the atmosphere to circumstances, the short summer of arctic America would be insufficient to clear the earth of the accumulated snows of nine months' winter. Professor Leslie, overlooking the powerful effect of direct radiation from the sun, and which indeed he could not know from experimenting only in an insular climate, was led from theory to fix the mean temperature of the pole at 32° F., and to declare that some great error must have pervaded all the thermometrical observations of Sir Edward Parry and the other arctic voyagers which showed the mean annual heat of places lying near the 70th parallel to be below zero. He has also described the whole of arctic America as involved in almost perpetual fogs; but this is true only of the sea-coast, and even there merely in some of the summer months, when fogs are produced by the intermingling currents of air of different temperatures, coming from the heated lands, the cooler open water or chilling masses of ice in the offing. Most of the winter nights are beautifully clear, and but for the intense cold, astronomical observations could be made nowhere in the northern hemisphere with more frequency.

* When air thus deprived of moisture is heated by admission into a warm room it causes all the wood-work to shrink in an extraordinary manner, and so dries and chops the cuticle of the human body that it readily becomes electric by friction with the palm of the hand, till the hairs stand erect, and a peculiar odour is evolved, like that which may be perceived when the rubber of an electrifying machine presses hard upon the cylinder.

No.	Locality.				Mean		
	Name of Place.	Latitude. N.	Longitude. W.	Altitude.	Of the Year.	Of six summer months, April to September.	Of six winter months, October to March.
		° ′	° ′	Feet.	°	°	°
1	Cumana	10 27	65 15	0	81·86	......	......
2	Havannah	23 10	82 13	0	78·08	......	......
3	Vera Cruz	19 11	96 01	0	77·72	......	......
4	Fort St. Philip (Louis.)	29 29	89 21	0	70·37	79·29	60·85
5	Pensacola	30 24	87 14	0	69·07	79·00	59·14
6	Baton Rouge	32 26	91 18	60	67·99	77·06	57·75
7	Xalappa	19 32	98 20	4330	67·64	......	......
8	Natchez	31 28	90 30	180	64·76	......	......
9	Mexico	19 26	99 05	7468	64·40	......	......
10	Norfolk (Virginia)	36 58	76 16	0	63·45	73·52	53·38
11	Annapolis	38 58	76 27	0	57·42	70·75	44·09
12	Toluca (Mexico)	19 16	99 21½	8823	57·20	......	......
13	Cincinnati	39 06	82 40	510	53·78	......	......
14	New York	40 40	73 58	0	53·78	......	......
15	Philadelphia	39 57	75 09	0	53·38	67·16	39 59
16	Detroit	42 19	83 00	564	53·08	68·70	37·44
17	Newport	41 30	71 18	0	52·09	64·87	39·30
18	Council Bluffs	41 25	95 43	......	50 68	68·67	32 65
19	Cambridge	42 25	71 03	0	50·36	......	......
20	Ft. Constitution (Maine)	43 04	70 49	0	47 91	61·39	34 42
21	Fort Niagara	43 15	79 05	240	47·48	61·60	33·36
22	Portland	43 38	70 18	0	46·47	61·12	31·81
23	Prairie du Chien	43 03	90 52	......	45·19	63·49	26 90
24	Penetanguishene	44 48	80 40	600	45·16	59·54	30·97
25	St. Peter's	44 53	93 08	680	44·12	64·01	24·23
26	Green Bay	44 40	87 00	600	44·06	61·68	26·44
27	Eastport	44 44	67 04	0	42·49	54·89	30·09
28	Quebec	46 47	71 10	0	41·74	......	......
29	Mackinac	45 51	85 05	600	40·12	55·31	24 94
30	Cumberland House	53 57	102 17	800	32·01	55·97	8·12
31	Fort Chepewyan	58 43	111 18	500	29·19	50·55	7 86
32	Nain	57 08	61 20	0	26·42	......	......
33	Churchill	59 02	92 05	0	25·30	......	......
34	Fort Reliance	62 46	109 01	350	21·47	......	......
35	Fort Franklin	65 12	123 13	200	17·24	39·95	−5·46
36	Fort Enterprise	64 28	113 06	850	14·19	37·78	−9·39
37	Winter Island	66 11	83 11	0	6·84	26·28	−12 59
38	Felix Harbour	70 00	91 53	0	5·29	27·71	−17·11
39	Port Bowen	73 14	88 55	0	3·62	23·64	−16·30
40	Igloolik	69 20	81 53	0	2·20	24·08	−19·68
41	Melville Island	74 47	110 48	0	−1·71	22·36	−25 79
42	East Coast of Greenland	70 to 74°	10 to 21° W.	0	......	......	......
43	Spitzbergen	79 21	10 to 11° E.	0	......	......	......
44	North of ditto	81½ to 82½°	17¼ to 24½° E.	0	......	......	......

NOTE.—The table is constructed upon the following authorities: 1, 2, 3, 8, 13, 14, 19,
10, 11, 15, 16, 17, 18, 20, 21, 22, 23, 25, 26, 27, 29, Keating, *Exped. to St. Peter's River,*
son, *Frankl. First and Second Journ*, *Ed. Phil. Journ.*, xi. p. 1;—37, 39, 40, 41, 44, Parry's
Greenl.

Temperature. Of three spring months, March, April, May.	Of three summer months, June, July, August.	Of three autumn months, September, October, November.	Of three winter months, December, January, February.	Of the warmest month.	Of the coldest month.	Number of months which have a mean temperature of 52° or above.	Sums of their temperatures.	Means of their temperatures.	Highest temperature recorded.	Lowest temperature recorded.	No.
°	°	°	°	°	°		°	°	°	°	
83·66	82·04	80·24	80·24	84·38	79·16	12	1062	81·86			1
78·98	83·30	78·98	71·24	83·84	69·58	12	937	78·08			2
77·90	81·50	78·62	71·96	81·86	71·06	12	933	77·72			3
70·56	82·89	72·75	54·08	84·31	51·59	11	789	71·66	92	+28	4
69·80	82·71	71·22	52·54	84·04	51·34	10	726	72·56	94	+20	5
69·40	82·36	68·92	51·28	84·80	49·71	10	714	71·44	99		6
......	69·32										7
65·48	79·16	66·12	48·56	79·70	46·94						8
											9
62·91	74·68	66·37	46·51	80·21	43·73	9	622	69·11	88	+20	10
56·08	73·37	62·60	34·31	79·88	29·28	8	540	67·47	92	+ 8	11
48·20											12
54·14	72·86	54·86	32·90	74·30	30·20	7	458	66·29			13
51·26	79·16	54·50	29·84	80·78	25·34						14
53·33	72·75	57·31	29·77	75·32	26·30	7	460	65·73	89	− 1	15
55·12	76·08	56·31	26·78	77·60	22·94	6	416	69·37	91	−14	16
48·53	71·16	57·79	30·87	74·02	26·30	6	399	66·45	86	0	17
52·68	77·03	50·76	22·23	79·62	12·80	5	363	72·56	104	−17	18
47·66	70·70	49·82	33·98	72·86	29·84						19
46·95	67·99	52·37	24·33	69·84	20·55	6	376	62·67	86	− 7	20
43·82	68·65	52·17	25·27	70·42	22·40	5	329	65·83	90	0	21
45·04	67·66	50·73	22·45	69·95	17·63	5	325	64·91	96	−10	22
44·16	71·76	46·60	14·93	73·66	6·20	5	337	67·39	94	−22	23
41·13	69·91	47·20	22·70	73·15	21·23	5	320	64·00	90	−32	24
47·47	72·88	44·57	11·65	75·47	3·26	5	340	68·06	93	−29	25
45·73	69·55	46·32	14·67	72·49	9·40	5	329	65·78	92	−23	26
39·90	60·85	50·95	21·60	62·32	17·53	4	242	60·42	88	− 9	27
38·84	68·00	46·04	14·18	73·40	13·81	5	318	63·60			28
37·09	64·11	45·02	14·27	67·34	10·53	4	249	62·29	86	−18	29
31·37	67·80	33·49	−4·62	73·73	−14·19	3	213	71·13	87	−44	30
23·96	62·41	34·08	−3·67	65·70	−9·56	3	187	62·40	97	−44	31
23·90	48·38	33·44	−0·60	51·80	−11·20						32
52·20	−6·80										33
12·71	......	......	−20·30	......	−25·00	......	......	......	......	−70	34
14·05	50·40	21·12	−16·60	52·10	−23·78	1	52	52·10	80	−53	35
8·72	51·71	19·34	−23·03	55·36	−29·12	2	109	54·28	78	−57	36
2·65	35·00	14·67	−24·96	36·68	−29·97	0	0	0	54	−42	37
−1·43	40·73	7·26	−28·70	44·57	−33·13	0	0	0	70	−47	38
−5·74	34·92	10·58	−25·09	37·29	−28·91	0	0	0	50	−47½	39
−2·19	34·63	3·12	−26·76	40·04	−32·80	0	0	0	50	−50	40
−6·94	36·44	−3·44	−33·02	42·41	−37·19	0	0	0	60	−55	41
......	34·53	......	......	35·29							42
......	34·50	......	......	35·98							43
......	......	......	......	33·13							44

26, 32, 33, Humboldt, *Mém. d'Arcueil*, iii. p. 462, and *Ed. Phil. Journ.*, iii. p. 1;—4, 5, 6, 1825;—7, Lyon's *Mexico*, Lond. 1828, ii. p. 196;—24, 30, 31, 34, 35, 36, Richard-*Voyages*;—38, Ross's *Second Voyage*;—43, Franklin, *Ed. Phil. Journ.*;—42, Scoresby's

Although the progress of colonization in the Atlantic States of North America has considerably restricted the range of the indigenous quadrupeds, and also somewhat modified the migratory movements of several groups of birds, we have no decided evidence that any one species has become extinct in that country through the agency of man; and ample opportunities are still afforded to the naturalist of making himself acquainted with the habits and structure of its ferine inhabitants. Whether we regard the striking peculiarities of the North American fauna, or the remarkable coincidence of most of its generic forms with those of Europe and Asia, and the considerable proportion of species common to both continents, its study is interesting and instructive to the general zoologist. But it is to the resident American naturalist that we especially look for a correct history of the animals which surround him. He has a field before him in a great part untrodden, and where cultivated, so overrun with weeds, that the fruit cannot be collected: for the early settlers having bestowed familiar European names on the specifically and in some cases generically distinct animals which they encountered in their new abodes, these were adopted by the naturalists of the Old World either without examination or after a comparison of dried and distorted exuviæ only. Mistakes thus originating are still suffered to encumber our systematic works, and the American zoologist will do good service to the branch of science which he cultivates, if, like the immortal Cuvier, trusting solely to his own powers of observation, he sits down on his own shore to dissect, examine, and reason for himself.

A correct view of the distribution of animals through the North American zoological province cannot be given until several large districts have been much more thoroughly investigated. Exclusive of deficiencies in our knowledge of the species which frequent the country lying to the eastward of the Rocky Mountains, the whole tract to the westward of that ridge, from Mexico to the Icy Cape, may be said to be as yet a *terra incognita* to zoologists. Of the animal productions of Russian America almost nothing has been made public since the days of Steller, with the exception of a few species described in the *Zoologischer Atlas* of Eschscholtz, now unfortunately brought to an abrupt conclusion by the death of its author. All that is known of the zoology of New Caledonia and the banks of the Columbia is derived from voyagers or travellers who have partially described the objects of chase by their popular names—the notices occurring in the narrative of Lewis and Clark being by far the fullest. The ornithological portion of the natural

history appendix to Captain Beechey's voyage by Mr. Vigors is our principal authority for the Californian birds; while the only professedly complete view of the Mexican fauna is the almost obsolete work of Hernandez. European museums, that of Berlin especially, have since the overthrow of the Spanish dominion in the New World obtained many specimens from Mexico, but we have not been able to procure a complete list of species, nor has the *Prodromus Faunæ Mexicanæ* announced by Professor Lichtenstein yet reached England. In the mean time we have had recourse to that author's elucidations of Hernandez (*Abhandl. der Ac. der Wissensch. zu Berlin*, 1827); to Deppe's sale list of Mexican specimens collected by himself, and M. Schiede, dated 1830; and to a paper by Mr. Swainson in the *Philosophical Journal* for 1827, describing one hundred species of Mexican birds: but as these papers do not notice the range of the species, they are very imperfect substitutes for Professor Lichtenstein's expected work.

From the geographical position of Mexico on the verge of the tropical region, the peculiar physical configuration of its surface, and its being the boundary between the northern and southern zoological provinces of America, it is the region which above all others is likely when properly studied to yield information respecting the laws which influence the distribution of animals. This has been well shown by Professor Lichtenstein in his paper in the *Berlin Transactions* already quoted. He compares the whole of New Spain to a great mountain, whose volcanic summit, attaining an elevation of 17,000 feet, enters within the snow line*, while its middle, temperate region is traversed by numerous valleys communicating at various heights, with wide basins, whose bottoms are little more than a thousand feet above the sea level. Hence the traveller journeying down the deep descent of one of these magnificent ravines through forests of beeches, oaks, and pines loaded with *cacti* and *epidendra*, finds himself suddenly on the level shores of the Rio Alvarado surrounded by palms, and has an opportunity of seeing the animal productions, of the north and south, of the alpine regions and tropics, nay of the eastern and western hemispheres, mingled together. Wolves of northern aspect dwelling in the vicinity of monkeys; humming birds returning periodically from the borders of the frozen zone with the northern buntings and soft-feathered titmice to nestle near parrots and curucuis; our common European whistling ducks,

* The observations of Humboldt place the inferior limit of perpetual snow within ten degrees of the equator in America at about 16,000 feet.

shovellers, gadwalls, and teals swimming in lakes which swarm with sirens (axolotl), and wherein the northern phaleropes seek their food in company with Brazilian parras and boatbills; associations which occur in no other region of the earth. Though the Mexican valleys or plains, having various altitudes, furnish appropriate stations for peculiar assemblages of animals, and by the common practice of the country the different regions are distinguished as "cold", temperate, and "hot", yet we know too little of the differences of climate to enable us to characterize these local faunæ with precision. It may be stated, however, that the low and hot maritime tract (*tierra caliente*) and the interior valleys nourish forms which have heretofore been considered as peculiarly South American, such as howling monkeys, hapales, armadillos, ant-bears, coatis, peccaris, coandus, jaguars, ocelots, maccaws, and ibises, though they do not range to the northward of the 19th degree of latitude *. This district also abounds in genera of birds common in the Brazils, (*icterus, tanagra, lanius*, and *muscicapa* † Linn.,) but on a close examination few of the species are found to extend to both continents.

In the temperate region, where the *cerealia* are cultivated, the animals accord little with those of South America, but resemble closely those of the east coast of North America—deer, opossums, skunks, rabbits, squirrels, and other gnawers replacing the southern monkeys and armadillos; in place of parrots there are party-coloured woodpeckers; and instead of tanagers and hepoazas we meet with thrushes, buntings, hedge-creepers, and warblers. The couracous, humming birds, and troupials go partially beyond this region to colder districts or higher latitudes; and it may be remarked of the couracous that they are larger and more brilliant in the elevated Mexican woodlands than in the Brazilian forests, while it may be affirmed of the troupials that they spread from their most congenial residence in the temperate regions of Mexico, northwards to the United States, and southwards to Cayenne and Brazil.

In the elevated cold region the fauna assumes an Europeo-Asiatic character. The fields abound with hares, the woods with squirrels; and a destructive sand rat, resembling the Canadian one, infests the maize grounds. There are also a spermophile scarcely differing from the Siberian one, the "cacamitzli" (*bassaris astuta*) a beast of prey of a new genus, one or two

* The Sais, Saguins, Sloths, Tapirs, and Tajasous, also Brazilian, do not exist in this district, but there are a few agoutis.—*Lichtenstein.*

† The genera Pipra, Todus, Myothera, Euphone, &c. are wanting in the warm district.—*Lichtenstein.*

species of skunk, some pretty weasels, (but no martins,) and a wolf very much like the Canadian species, which descends also to the warmer valleys. The white-head sea-eagle, the Virginian horned owl, the common barn owl*, and a smaller species, with sparrowhawks and falcons are the common birds of prey in the cold region, where the Brazilian urubitingas and naked-headed carrion vultures also come. Snow-birds, buntings, grosbeaks, a great variety of finches, and a peculiar kind of long-legged ground cuckoos are the chief singing birds, and among the water-fowl which cover the extensive alpine lakes there are at least ten or twelve of our northern ducks. Terns and gulls seldom fail to appear at certain seasons, but they are species that have been described by Hernandez alone, and are not yet introduced into our systems †. These remarks, though greatly abridged from the original, will serve to show how much the North American fauna in general would be elucidated by an investigation of that of Mexico.

In the following observations on the *Mammalia*, the arrangement of Cuvier's *Règne Animal* is adopted.

Ord. QUADRUMANA.

One animal of this order (*inuus silvanus*) ranges in the Old World northward to the rock of Gibraltar, lying in the 36th parallel, but we are informed by Lichtenstein that no monkey has been observed in the New World beyond the 29th degree of north latitude. Mr. Ogilby again tells us that there are no real *quadrumana* in America ‡, none of the monkeys inhabiting that quarter of the globe having a thumb truly opposable to the fingers, and he has therefore proposed to arrange them in a group named

* There is reason to believe that many owls which have heretofore been considered as only geographical varieties of the *Strix flammea* are in fact distinct species, though closely resembling the European type.

† The views of Mr. Swainson with respect to the junction of the North and South American zoological provinces in Mexico correspond generally with those of Lichtenstein, though these authors do not appear to have been acquainted with each other's labours on that subject. Lichtenstein's paper is of a prior date to the *Geographical Dictionary* or Mr. Swainson's Treatises in *Lardner's Cyclopædia.*

‡ Ogilby, *Zool. Proc.*, No. 39, 1836. " In *ateles* the thumb is either merely rudimentary or entirely absent; in *mycetes, lagothrix, aotus, pithecia* and *hapale* it is similar to the other fingers and in a line with them; while in *cebus* and *callithrix*, though placed a little further back than the other fingers, it is weaker, and acts in the same direction with them, never in opposition to them." " None of the true *quadrumana* have prehensile tails." The American monkeys have other peculiarities, of which the most characteristic are their lateral nostrils. That they rarely sit erect is indicated by their hairy buttocks.

pedimana, which with the exception of the phalangers of the Indian archipelago is proper to the New World and to Australia. There are no apes nor baboons without tails in the group; even the callosities of the buttocks are wanting, and a large proportion of the species have prehensile tails endowed with so great a delicacy of touch that they have been compared to the trunk of the elephant. This modification of structure evidently indicates great capability of travelling from tree to tree in lofty and crowded forests, and it is worthy of remark that America excels the other quarters of the world in the variety of animals which use the tail as an organ of prehension or progression among trees, for not only the genera *mycetes*, *brachyteles*, *ateles*, *lagothrix*, and *cebus* among the *quadrumana* possess this power, but also *didelphis* among the *marsupiata*, *cercoleptes** ranking with the *carnivora*, and *syntheres* and *capromys* with the *rodentia*.

The monkeys which enter the southern provinces of Mexico belong to the genera *mycetes* and *hapale*†.

Ord. CARNIVORA. *Fam.* CHEIROPTERA.

The members of this family which have hitherto been detected in North America belong to that tribe of the "true or insectivorous bats" which Cuvier has characterized as possessing only one bony phalanx in the index, and two in each of the other fingers. This is in fact the only tribe of *cheiropteræ* which is distributed generally over the world, and to it all the European bats belong, with the solitary exception of the Italian *dinops Cestonii*. The other subdivision of the true bats, comprising *molossus*, *dinops*, *nyctinomes*, *cheiromeles*, *noctilio* and *phyllostoma*, is chiefly South American, though it has a few representatives in the warmer regions of the old continent. *Phyllostoma*, the most remarkable of the generic groups, is indeed peculiar to the new world; but *phyllostoma spectrum*, placed by Geoffroy in a distinct genus named *vampirus*, is the only species which authors have mentioned as ranging northwards to New Spain‡.

The following bats have been noted as inhabitants of the United States and British America; and though they almost all belong to the cosmopolitan genus *vespertilio*, none of the American species have been detected in other countries.

* The closest affinities of cercoleptes are with the *ursiform plantigrada*.—Owen, *Zool. Proc.*, No. 32, 1835.

† "Brüll-affen" and "Klammer-affen."—Lichtenstein, *op. cit.*, p. 97.

‡ Desmar. *Mamm.*, Griff. *Cuv.*, &c.

Rhinopoma carolinensis, GEOFF. *Mus.**	*Vespertilio monachus*, RAF.
Taphozous rufus, WILS. *Am. Or.* 50.	„ *phaiops*, ID.
Vespertilio carolinensis, GEOFF. *Mus.* 47.	*Plecotis megalotis*, ID.
„ arquatus, SAY. *Long's Exp.*	*Nycticeius noveboracensis*, PENN. 31, 2.
„ subulatus, ID. *Ib.*	„ *humeralis*, RAF.
„ *Audubonii*, HARLAN.	„ *tessellatus*, ID.
„ *melanotus*, RAFINESQUE.	„ pruinosus, GODM. *p.* 72. *f.* 3.
„ *calcaratus*, ID.	*Hypexodon mystax*, RAF.
„ *cyanopterus*, ID.	

The first species of the above list is in Geoffroy's opinion not a true *rhinopoma*, and the native country of the only individual which has been seen is very doubtful †. The red bat of Pennsylvania is the only American *taphozous*, the other members of the genus being inhabitants of Africa and the East Indies. The remaining bats of the list are analogous to those of the temperate parts of Europe; but most of the species are still imperfectly described, nor have their distinctive characters been properly investigated, and consequently nothing certain can be stated respecting their distribution. It can scarcely be matter of surprise that these nocturnal animals are so little known in the New World, when we consider that though Pennant described only five species as natives of Great Britain, seventeen are figured in Mr. Bell's recent work. The American bats which have been admitted into systematic works, on M. Rafinesque's authority, have been named rather than characterized; and few of the many genera proposed by this author have been adopted by naturalists, owing to his want of precision and inattention to structure. His labours are not, however, to be entirely disregarded; for he has certainly detected many new animals both in Europe and America, being one of the first investigators of the natural history of the latter country who was not prevented from judging for himself by an overweening deference to European authority. His genus *nycticeius*, characterized by having only two widely separated upper incisors, includes a considerable number of species hitherto ranged with *vespertilio*, and according to M. Temminck comprises even the genus *atalapha*, which Rafinesque had incorrectly founded on the *vespertilio noveboracensis*, from a supposed want of these two incisors, which nevertheless exist. The characters of *hypexodon* are equally vague, and it is not likely that any one of these three genera will be permanently adopted. *Nycticeius pruinosus* has been taken on the Saskatchewan, the Missouri, and at Philadelphia; and *vespertilio subulatus*, having a range

* The doubtful species, or those which particularly require further elucidation, are in *italics*.

† Desmar., *l. c.*

of 24 degrees of latitude from the Arkansas to Great Slave Lake, is probably the most generally diffused of the American bats.

Ord. CARNIVORA, cont. *Fam.* INSECTIVORA.

Sorex brevicaudus, SAY, *Long's exp.*	Condylura cristata, GODM. *pl.*
„ parvus, ID.	„ *longicaudata*, RICH. *F.B.A.*
„ personatus, GEOFFR. *Mus.* 15, 122.	„ macroura, HARL. RICH. *F.B.A.* 24.
„ Forsteri, RICH. *F.B.A.*	„ *prasinata*, HARRIS, LESS. *man.*
„ palustris, ID. *Ib.*	Scalops canadensis, GODM. *pl.*
„ *talpoides*, GAPPER, *Zool. J.* 5.	

In no other family of *carnivora* do the North American members differ so much from the European ones as this, the range both of generic forms and of species being more than usually restricted within certain geographical limits. None of the family are known to inhabit South America; the European genera *erinaceus, talpa,* and *mygale* have not been detected in North America, while *condylura, scalops,* and all the shrews in the above list are peculiar to the latter country. *Cladobates, centenes,* and *chrysochloris* belong to the East Indies, Madagascar, and the Cape of Good Hope, the supposed American species of the last-mentioned genus (*chrysochloris rubra vel rufa*) having no other authority for its origin than that of Seba, upon which very little dependence can be placed.

The shrews above enumerated closely resemble their European congeners, with whom they have not been sufficiently compared; *palustris* in particular is with difficulty distinguishable from *fodiens* or *Daubentonii.* Little has been done towards determining the range of the North American species. Those which inhabit the Atlantic states were formerly considered as identical with European species; but after Mr. Say, in his expedition up the Missouri, had detected and described as new *brevicaudus* and *parvus*, these names were applied to the coast shrews, though it is by no means certain that they are more appropriate than the older appellations. *S. brevicaudus* is said by Mr. Taylor* to be an inhabitant of the Alleghany range, at the height of 2000 feet above the sea, where during the winter it makes long galleries in the deep snow. *S. palustris* and *Forsteri* have a high northern range, extending within the arctic circle to the limit of the woods. The latter differs from the description of *S. personatus* principally in wanting a black mark on the end of the nose and in the colour of the under fur, so that without a comparison of specimens they cannot be positively pronounced to be distinct. *S. talpoides,* the

* *Mag. Nat. Hist.*

largest of the American shrews, was detected in Canada by Dr. Gapper, who has deposited a specimen in the Bristol museum. The distribution of *condylura* and *scalops* has been but partially traced, but it is probable that they do not extend beyond the 53rd parallel. Mr. Taylor captured the *scalops canadensis* on the north eastern end of the Alleghanies at an elevation of 1500 feet, while the *condyluræ* were confined to the bottom meadow lands. Lichtenstein thinks it probable that the moles entirely destitute of sight mentioned by Hernandez as inhabitants of Mexico, belong to the genus *scalops*. Authors disagree in their accounts of the dentition of the *scalopes*. Baron Cuvier says that they have the teeth of the desmans, and such is the case in the specimens which I have examined, the total number of teeth being 44. Desmarest enumerates only 30 teeth in all, and Dr. Godman, who is followed by Lesson, reckons 36. Harlan describes a species (*pennsylvanica*), of which he has merely the skeleton, possessing 40 teeth. The teeth of the Canadian species round away by use in a very remarkable manner, so as to look like rows of seed pearls. The genus of the animal named "black mole," considered by some as a *talpa*, is uncertain, but it is most likely a *scalops*: Mr. Taylor found it on the Alleghany range. The *condyluræ* would form an interesting subject for a monograph; the species are, perhaps, more numerous than has hitherto been suspected, and their manners are as yet almost unknown. The remarkable enlargement of the tail, which has given origin to one of the specific appellations, is, according to Dr. Godman, merely a sexual peculiarity confined to certain seasons.

Ord. CARNIVORA cont. *Fam.* CARNIVORA.

DIV. 1. *Plantigrada.*

Ursus arctos*? RICH. *F.B.A.*
„ ferox, ID. *l. c.* 1.
„ americanus, F. CUV. *Hist. des Mam.*
„ maritimus, ROSS, *Voy. pl.*
Procyon lotor, BUFF. 8, 43.
Nasua, *species duæ*, LICHT. HERN.
Meles labradoria, RICH. *F.B.A.* 2.
Gulo luscus*? EDW. 103.
„ barbara, GRIFF. CUV. *pl.*
Bassaris astuta, LICHT. HERN.

DIV. 2. *Digitigrada.*

Putorius vison, BUFF. 13. 43.
„ *vulgaris**? PENN. *Arct. Zool.*
„ *erminea**? ID. *Ib.*
Mustela canadensis, GMEL. RICH. *F.B.A.*
„ { *huro*, F. CUV. *Dict. des Sc.* 29.
„ { *martes**? RICH. *F.B.A.*
Mephitis americana, SABINE, *Fr. Voy.*
Mephitis nasua, BENN. *Zool. Proceed.*
„ *putorius*, CATESB. 62.
„ *interrupta*, RAF. *An. of Nat.*
„ *vulpecula*, FISCH. *Syn.*
„ *myotis*, ID. *Ib.*
„ *itzqui-epatl*, HERNANDEZ, *Mex.*
„ *conepatl*, ID. *Ib.*

Lutra canadensis, Fr. Cuv. *B. des Sc.* 27.
„ lataxina*? Id. *Ib.*
Enhydra marina*, Cook, *Third Voy.* 43.
Lupus occidentalis, Rich. *F.B.A.* 3.
„ mexicanus, Lin. Licht. Hern.
„ latrans, Rich. *F.B.A.* 4.
„ ochropus, Eschsch. *Zool. Atl.* 2.
„ *nigrirostris*, Licht. Hern.
Vulpes lagopus*, Thien. *Nat. Bem.*
„ *isatis*, Id. *Id.*
„ fulvus, Rich. *F.B.A.* 5.
„ cinereo-argentatus, Schreb.
„ velox, Say, *Long. Exp.*
Felis *onca*, Fr. Cuv. *H. des Mam. pl.*
„ discolor, Cuv.
„ *pardalis*, Griff. Cuv. *pl.* y.
„ rufa, Schreb. 109, 13.
„ *mitis*, F. Cuv. *H. des Mam.* No. 18.
„ canadensis*? Geoff.
„ *Griffithsii*, Fisch. *Syn.* Griff. *Cuv. Ocel.* 3.
„ *chiliguoaza*, Fisch. *Syn.* Griff. &c. *Ocel.* 4.
„ *maculata*, Horsf. & Vig. *Zool. J.* 4, 13.

It is to this great family that the terrestrial quadrupeds which are common to the old and new continents mostly belong. The generic forms are those of Europe, with a few exceptions, such as *procyon*, *nasua*, *bassaris* and *mephitis*, which seem to be stragglers from the South American zoological province. On the other hand, the genus *lutra*, which is a northern form, sends a few species to the south of the Isthmus of Darien.

Plantigrada.—Two bears of the preceding list are peculiar to the New World, namely *ferox* and *americanus*, the former dwelling principally in the Rocky Mountains, but occasionally descending to the neighbouring prairies, while the latter inhabits all the wooded districts from Carolina to the Arctic Sea, being, however, less numerous near the coast. The *maritimus* is common to all the northern regions, but it ought in fact to be considered rather as a sea animal than a land one: it traverses the whole of the icy seas from Nova Zembla and Spitzbergen to Greenland, and from thence along Arctic America to the shores of Siberia. It is, in fact, the most northern quadruped, having been seen by Sir Edward Parry in the 82nd degree of latitude, and it descends on the Labrador coast to the 55th. The males, and females that are not gravid, travel far in the winter time over the ice in quest of food*. The *ursus arctos* does not range in America much to the south of the Arctic circle, being confined to the "barren-grounds:" its identity with its European namesake has not been been properly established. Lichtenstein, in his observations on the work of Hernandez, mentions two or three species of *nasua* as existing in Mexico, one of them being white with large black spots. The raccoon (*procyon lotor*) ranges from Canada as far south, it is said, as Paraguay: on the coast of the Pacific, its skins are ob-

* Vide *App. to Capt. Back's Journey*, wherein an instance is quoted of a whale having been killed by the crew of a vessel which was beset in the winter by ice 60 miles from the land. Next day many bears and arctic foxes came to feed on the crang!!

tained by the fur-dealers up to latitude 60°, but more correct observations as to the identity of the species are required before so extensive a range can be ascribed with certainty to this animal. Mr. Collie, when with Captain Beechey, saw a small ursine animal very abundant on the coast of California, which is probably the *procyon cancrivorus* or an allied species.

The *meles labradoria*, which is perfectly distinct from the European badger, has its northern limit about the 55th parallel, where it inhabits the prairies only. The *meles hudsonius*, mentioned by Cuvier in the *Règne Animal* as differing very little from the *meles vulgaris* of Europe, is entirely unknown to us. The Mexican species, supposed to be indicated by Hernandez, is very doubtful. The wolverene (*gulo luscus*) does not vary, according to Cuvier, from the European glutton by permanent characters; next to the polar bear and arctic fox it is the most northern carnivorous quadruped, its range extending to Parry's Isles in latitude 75° N., if not to a still higher parallel. *Gulo barbara*, enumerated by Lichtenstein in his list of Mexican animals, extends southwards through all the warmer districts of America. Mr. Gray pointed out to me its closer resemblance in external form to the weasels than to the northern glutton, and its differences from the latter in the form of its feet, which, though plantigrade, are slightly webbed, in its long tail, and in its having a tooth fewer in each jaw; it should therefore be separated, together with its allied species, in which case *gulo* would remain entirely a northern genus. *Bassaris astuta* is a Mexican animal, noticed by Hernandez under the name of *tepemaxtlatan*, which has characters intermediate between *viverra* and *nasua*, and is therefore placed in a new genus by Lichtenstein.

Digitigrada.—The American weasels and martins have greatly perplexed naturalists, and their synonyms are involved in much confusion; yet we can pretty confidently assert that five species only are known in the fur-countries from latitude 50° N. to the Arctic sea. The range of the described species is limited to the northern or middle districts of the United States; but Lichtenstein informs us that some new kinds inhabit the elevated lands of Mexico. The ermine has been seen as high as the 73½ degree of latitude on the west side of Baffin's Bay*. It is very probable that both the ermine and stoat of America are distinct species from those of the old continents, the superior quality of the fur of the Siberian ermine being one marked difference; while there are others, such as the much smaller skull of the

* Sir J. Ross, *First Voyage*.

American animal, which will be more readily acknowledged by naturalists. Baron Cuvier holds the *putorius vison* to be a distinct species from the *mustela putorius* of Europe, though some zoologists confound them*; it ranges from Carolina to the arctic sea. The pine-martin of America is also most probably a different species from the European one, and in fact the comparisons of Mr. Yarrell have shown that in the form of its skull it approaches more closely to the *martes foina*, or beech martin. Most of the American martins noticed by authors we believe to be merely nominal species; thus the *huro* of Frederick Cuvier is the common American pine-martin in its pale summer dress, and the same is most probably the case with the *lutreocephala* of Harlan†, while the *zibellina* of American naturalists is the same animal in its prime dark winter fur. The pine-martin ranges northwards to the limits of the woods, and many specimens corresponding with the descriptions of *huro* and *lutreocephala* were observed at Fort Franklin, where the natives considered them, and the darker and often smaller martin sold by the furriers under the name of sable, to form only one species‡. The *m. vulpina* of Rafinesque and *m. leucopus* of Kuhl require further investigation.

The "fisher", or "wejack" (*mustela canadensis*), is found up to the 60th parallel. Its synonymy is embroiled in confusion, which is attempted to be unravelled in the *Fauna Boreali-Americana*; but on referring to Fischer's synopsis, we discover that it has more recently received other appellations, and among the rest that of *mustela Godmanii*, apparently from an apprehension that the animal described in Dr. Godman's natural history is either a distinct species or a well-marked variety. Now, on referring to this description, we observe that it is substantially the same with that drawn up by Mr. Sabine (in the appendix to Sir John Franklin's first journey) of the common wejack, or woodshuck, with the single addition of "tail smallest at the end", which is not really the case in the wejack.

The *mephitis americana* ranges northwards to the 61st parallel§, but its southern limits cannot be ascertained until the species are more clearly defined. Some authors consider every

* Fischer, probably misled by Pennant's miserable figure of the animal in the *History of Quadrupeds*, has named a fictitious species *enhydra gracilis*. (*Synops.*)

† Dr. Godman says that the original specimen described by Dr. Harlan under the appellation of *lutreocephala* is an overstuffed vison, long kept in Peale's museum.

‡ Vide Yarrell's *Zool. Jour.* for 1836.

§ Vide King's *Narrative of Capt. Back's Journey*. Bentley, 1836.

individual differing in the distribution of its stripes as a distinct species, while Cuvier ranks them all as mere varieties, thus attributing to the animal a most extensive range through North and South America. The *americana,* which is the most northern species, is very uniform in its markings within the limits of the fur countries. Kalm describes one differently zoned as an inhabitant of Canada; the *bête puante,* discovered by Du Pratz in Louisiana, has been named *mephitis* ? *myotis* by Fischer; Rafinesque distinguishes the *mephitis interrupta* of the same country; and Hernandez points out two Mexican skunks by the names of *itsqui-epatl* and *cone-epatl.* The *m. nasua* is an inhabitant of California. There is, perhaps, an error in the statement made by some naturalists, that the South American *mephitis chincha* extends its range to the southern parts of the United States, for though the Baron finds the osteological characters of all to be the same, the varieties distinguished by the number and distribution of their stripes do not usually occur together in the same districts, nor range through many degrees of latitude.

According to Baron Cuvier, the *lutra canadensis,* which extends northwards to the vicinity of the polar sea, is the same species with the *brasiliensis*; and the *lataxina* has an almost equally extensive range from Great Slave Lake, where it was found by Mr. King, to Carolina, where F. Cuvier's specimens were obtained, and the Brazils, whence the Baron received it. The variety of climates inhabited by *lataxina* will be still more remarkable if, as Cuvier seems to intimate, it be specifically the same with the European otter, for he says they do not differ by any permanent characters. Even the domestic dog does not change his abode to the same extent without undergoing more sensible alterations of form. Were the otter to live entirely in the water, the severity of the seasons would be greatly tempered to it; but it is wont in the high northern latitudes to travel far through the snow in quest of open water when its summer haunts are frozen up.

With regard to the species of the genus *canis* much difference of opinion will most likely continue to prevail among naturalists, from the general uniformity of their external forms, the great difficulty of characterizing the differences by brief descriptions, and the want of a sufficient number of specimens in any one collection for comparison. The physiognomy of the American wolf when contrasted with that of its European namesake is very distinct; but a family likeness prevails throughout the whole group of American wolves, however much they may differ in size, colours, or even in habits. The *lupus occidentalis*

travels northwards to the islands of the Arctic Sea, but its southern range cannot be defined until its identity with the common wolf of the United States be proved or disproved. According to Lewis and Clark, the latter crosses the continent to Upper California. The Mexican wolf seems to differ from *occidentalis* chiefly in the black parts of the fur forming bands on the flanks; an accurate comparison of the two is still required. *Canis latrans*, or the prairie wolf, is found on the Saskatchwan and Missouri, being confined, as its name imports, to the prairie lands. It is probable that the Californian *ochropus* and the Mexican *nigrirostris* are but varieties of *latrans*. Authors are not more decided with respect to the species of foxes. Cuvier thinks that the *canis fulvus* differs from the European *vulpes* merely in having more brilliant fur; but, as Mr. Bennett has remarked, it is impossible for any one to contemplate the two species together in the Zoological Gardens without observing their very different aspects: the black, silver, and cross foxes of the furriers are mere varieties of *fulvus*. A notion exists in the United States that the descendants of European foxes introduced by the early settlers are now numerous in the country, but the fact has not been established by a decisive comparison of specimens, and it is possible that the animal of supposed European origin is the Virginian fox (*cinereus* or *cinereo-argentatus* of Schreber), which at certain seasons has a reddish hue. The latter ranges from Upper Canada across the continent to the banks of the Columbia, southwards to the Gulf of Mexico, and, according to Cuvier, throughout tropical America. The kit-fox (*velox*) is peculiar to the prairies, and does not go higher than the 55th parallel of latitude; it is very similar in habits to the Asiatic *corsac*. Thieneman has distinguished two species of arctic fox, which were formerly confounded under the name of *lagopus*. One for which he has retained this appellation is stated in Fischer's synopsis to be an inhabitant of Europe only; but it is the species which frequents the arctic coasts of America as far west as Mackenzie's River, and descends along the shores of Hudson's Bay to the 58th parallel. The other species, named *isatis*, characterized by its acute ears and coloured tip of the tail, is said to be an inhabitant of the northern parts of Asia and America; but I suspect that its range in the latter country is confined to the west side of the Rocky Mountains, as it did not fall under my observation to the eastward. On the Pacific coast the arctic fox is said to occur as far south as the 58th or 59th degree of latitude.

The confusion of synonyms in the genus *felis* is not less per-

plexing than in that of *canis*, and though the labours of F. Cuvier, Temminck, and others have expunged several nominal species from the American fauna, no dependance can be placed on the accounts which previous writers have given of their distribution. Temminck has remarked that there is no proof of either *felis onca* or *pardalis* having been killed in North America; but both these and the puma, or cougar (*concolor*), are mentioned by Lichtenstein as inhabitants of Mexico, probably on the authority of specimens communicated by Messrs. Deppe and Schiede. The puma is decidedly common to North and South America: Langsdorff observed it in Upper California, Dr. Godman adduces authenticated instances of its having been killed in Kentucky and New York, and it is said to have strayed occasionally as far north as Canada. The existence of the jaguar (*onca*) within the limits of the United States is more doubtful, though Lewis and Clark say that they saw it on the banks of the Columbia, and Dr. Harlan includes both it and the ocelot (*pardalis*) in his fauna of the United States. In neither case, however, have we any information respecting the means used for identifying the species; and as *felis mitis*, now known to range northwards to Mexico*, was confounded with *pardalis* until its peculiar characters were pointed out by F. Cuvier, we are not in a condition to say which of the two enter the United States, if, indeed, either of them come so far north. According to Temminck, *felis rufa* inhabits every part of the United States, but does not exist in Canada: it ranges to the banks of the Columbia, and Mr. Bullock found it in Mexico. The peeshew, or *felis canadensis*, is the most northern of the cat-kind, being, in fact, the only species which extends beyond the Canada lakes, whence it ranges through the woody districts of the fur-countries up to the 66th parallel. Temminck states that it is also an inhabitant of the northern parts of the Old World, and he has therefore proposed to change its name to *borealis*. The name of *canadensis* having been occasionally given to the bay lynx by the naturalists of the United States, erroneous impressions of the southerly range of the former have been produced. *Felis carolinensis* and *mexicana* of Desmarest, and *montana*, *floridana*, and *aurea* of Rafinesque, are doubtful species, the occurrence of whose names in systematic works shows the necessity for extended and correct observations by resident naturalists. The *lynx fasciatus* of the latter author is founded upon Lewis and Clark's description of a cat killed by them on the banks of the Columbia; but the species requires further eluci-

* Lichtenstein. It is supposed to be the jaguar of New Spain of Buffon.

dation before it can be considered as established. Lieutenant-colonel H. Smith has figured two ocelots in Griffith's Cuvier, —No. 3, which came from Mexico, and was preserved in Bullock's museum, and No. 4, which he supposes to be a native of the same country, and to be the species figured by Buffon, Supp. 3, 18. The former is named *f. Griffithsii*, and the latter *f. chibiguaza* in Fischer's synopsis. The *felis maculata* of Horsfield and Vigors, figured in the Zoological Journal, was brought from Mexico by Captain Lyon.

Ord. CARNIVORA, cont. *Fam.* AMPHIBIA.

Calocephalus vitulinus*, F. CUV.	Otaria jubata, PERON.
„ fœtidus*, FABR.	„ ursina, ID.
„ hispidus*, SCHRÖB.	„ pusilla, BUFF. 13, 53.
„ grönlandicus*, EGEDE.	„ californiana, CHORIS, *Voy.* 11.
„ lagurus, F. CUV.	„ Stelleri, LESS. FISCH. *Syn.*
„ barbatus*, FABR.	Trichechus rosmarus*, LIN.
Stemmatopus cristatus*, GMEL.	

Few of the amphibious carnivora enumerated above are peculiar to America, for though the *otariæ* are found only in the Pacific, they range to its Asiatic as well as the American shores; the others are mostly common to the northern seas of Europe, Asia, and America. As it is only of late years that the seals of Europe have been investigated with any success, there is little probability of the American list being either correct or complete*.

Captain James Ross states that the smaller seals (*vitulina fœtida* and *hispida*) come into the bays and near to the shores of the arctic seas in winter, living under the ice, in which they preserve breathing-holes; while the harp and great seals (*groenlandica* and *barbata*) keep at a distance from the land among the packed ice and partially open water. *Calocephalus lagurus* was sent from Newfoundland by De la Pilaye, and it is probable that *leucoplus* (THIEN.), which inhabits Iceland, ranges over to Greenland and Davis's Straits, in which case it belongs also to the American fauna. The leonine seal (*stemmatopus cristatus*) descends further southwards on the American coast than elsewhere, one having been captured near New York. This specimen has been described as a distinct species under the name of *mitrata* (Fischer, *syn.*). Most of the Davis's Straits seals have been enumerated by authors as inhabitants also of the sea of

* All the *calocephali* of the above list, except *fœtidus* and *lagurus*, are mentioned by Graah as inhabitants of the east coast of Greenland, as are also *stemmatopus cristatus* and *trichechus rosmarus*. (Vide *Exp. to East Coast of Greenland*, by Capt. W. A. Graah.)

Kamschatka. Of the *otariæ* which also frequent the sea just named, *jubata* is said, though without satisfactory evidence, to exist also in the Straits of Magalhães. *O. Stelleri* is very imperfectly known, even the genus to which it belongs being uncertain. The existence of the *otaria fasciculata*, or the "ribbon seal", is surmised merely because a piece of back-skin was transmitted from the Kurile islands to Pennant, and figured by him in the *History of Quadrupeds.*

The *trichechus rosmarus* is found in all the arctic seas, though there are some deep sounds, such as Regent's and Bathurst's Inlets, into which it does not enter. It descends along the Labrador coast to the Magdalene islands, in the 47th parallel.

Ord. MARSUPIATA *.

Didelphis virginiana, GRIFF. CUV. *pl.*
„ opossum, BUFF. 10, 45, 46.
Didelphis cancrivora, GRIFF. CUV. *pl.*

As the marsupial animals are now confined to America, New Holland, and some parts of the Indian archipelago, and geological researches indicate that they are the earliest mammiferous animals whose remains exist in the ancient strata of the earth, the study of these zoological provinces must be interesting to those who seek to develope the condition of the world at former periods. Comparative anatomists have shown that the *marsupiata* are inferior to other *mammalia* in their simple unconvoluted brain, less perfect organs of voice, and lower intelligence; the *rodentia* are next to them in these respects; and the existence of *marsupiata* and the great numbers of *rodentia* in the North American fauna are its chief characteristics when contrasted with that of Europe. It has been said that when the ancient *marsupiata* existed they were exposed to the attacks of no enemy having higher intellectual powers than a reptile. In the present day the opossums of America and the phalangers of India have many enemies of different classes, yet they do not seem to be in any immediate danger of extinction; and the more numerous marsupials of Australia are kept sufficiently under by carnivorous beasts of their own order, aided by birds

* Though Cuvier has arranged the *marsupiata* as an order, he considers it rather as forming a division, or subclass, parallel to the rest of the mammalia, and representing all the other orders. Mr. Owen agrees with him in observing, that "the marsupials, including the monotremes, form a very complete series, adapted to the assimilation of every form of organic matter." M. Desmoulins and Mr. Swainson have distributed them among the several orders, esteeming what Cuvier supposed to be merely analogies to be in reality affinities. The *didelphidæ* being carnivorous, are not, in either view of the matter, out of place at the end of the *carnivora.*

of prey, and above all by man and his attendant dog. In the order *rodentia* we have an example of productiveness being sufficient to ensure the species from extinction, though assailed by hosts of foes of all kinds.

Only one *didelphis* is common to North America, namely, the *virginiana*, which extends to the Canada lakes, being, moreover, like the rest of the genus, an inhabitant of the intertropical parts of the continent. Mr. Collie saw it in California, and Temminck says it inhabits Mexico. *Didelphis cancrivora* and *opossum* range, according to Lichtenstein, as far north as Mexico, and if one of these be not the "coyopollin" of Hernandez, there is a fourth species in that country. Authors have somewhat arbitrarily used the name of coyopollin as a synonym of *dorsigera* and *philander*; but it is by no means certain that the latter species reaches Mexico.

Ord. RODENTIA.

Sciurus cinereus, Buff. 10, 25.
" capistratus, Griff. Cuv. *pl.*
" ? *grammurus*, Say, *Long. Exp.*
" niger, Rich. *F.B.A.*
" Colliæi, Id. *Beech. App.* 1.
" Clarkii, Smith, *Griff. Cuv. pl.*
" Lewisii, Id. *l. c. pl.*
" hudsonius, Rich. *F.B.A.* 17.
Tamias Lysteri, Id. *F.B.A.* 15.
" quadrivittatus, Id. *F.B.A.* 16.
" *buccatus*, Licht. *Deppe's List.*
Pteromys sabrinus, Rich. *F.B.A.*
" alpinus, Id. *l. c.* 18.
" volucella, Buff. 10, 21.
Spermophilus lateralis, Rich. *F.B.A.* 13.
" Hoodii, Id. *l. c.* 14.
" Richardsonii, Id. *l. c.* 11.
" Franklinii, Id. *l. c.* 12.
" Beecheyi, Id. *l. c.* 12 B.
" Douglasii, Id. *l. c.*
" Parryii, Id. *l. c.* 10.
" *guttatus*? Id. *l. c.*
" spilosus, Benn. *Zool. Pr.*, 1833.
" ? Ludovicianus, Griff. Cuv.
Arctomys empetra, Rich. *F.B.A.* 9.
" ? *brachyurus*, Harlan, *fauna.*
" *pruinosus*, Penn.
" *caligatus*, Eschsch. *Zool. At.* 6.
" *ochanaganus*, King, *Narr. &c.*
" monax, Edw. 104, Griff. Cuv.
Mus leucopus, Raf. Rich. *F.B.A.*
" ? *virginicus*, Reich. Fisch. *Syn.*
Meriones labradorius, Rich. *F.B.A.* 17.
Neotoma Drummondii, Rich. *F.B.A.* 8.
" floridana, Say & Ord. *Ac. Sc. Ph.*
Sigmodon hispidum, Say.
" *ferrugineum*, Harl. *Sill. Jour.*
Fiber zibethicus, Cuv.
Arvicola riparius, Ord.
" xanthognathus, Leach. *Zool. M.*
" pennsylvanicus, Rich. *F.B.A.*
" noveboracensis, Id. *l. c.*
" borealis, Id. *l. c.*
" *rubricatus*, Id. *Beech. App.*
Mynomes pratensis, Raf. *An. Nat.* 1820.
Georychus helvolus, Rich. *F.B.A.*
" trimucronatus, Id. *l. c.*
" hudsonius, Id. *l. c.*
" groenlandicus, Id. *l. c.*
Geomys bursarius, Davies, *Lin. Tr.* 5, 8.
" borealis, Rich. *nov. sp.*
" Douglasii, Id. *F.B.A.*
" bulbivorus, Id. *l. c.* (*diplostoma*).
" umbrinus, Id. *l. c.*
" talpoides, Id. *l. c.*
" *pinetis*, Raf.
" Drummondii, Rich. *nov. sp.*
" mexicanus, Licht. Hern.
Saccomys anthophilus, F. Cuv.
" *fasciatus*, Raf. (*Cricetus*).
Apluodontia leporina, Rich. *F.B.A.* 18 C.
Castor fiber* ?, L.
Eretizon dorsatum, Griff. Cuv. *pl.*
Synetheres prehensilis, F. Cuv.
Lepus glacialis, Leach.
" americanus, Gmel.
" *virginianus*, Harl.
" *mexicanus*, Licht.
" *cunicularius*, Id.
Lagomys princeps, Rich. *F.B.A.* 19.
Dasyprocta carolinensis, F. Cuv.

North America exceeds the other quarters of the world in the

number of species and variety of forms of its rodent animals; but they are still very imperfectly known, as their original describers have too frequently contented themselves with noticing the colour of the fur and the length of the tail, disregarding osteological characters, and rarely noting the dentition, so that many of the species enumerated in the American fauna are of uncertain genera, and many nominal ones have been introduced. The American naturalist who shall sedulously collect *rodentia* from various parts of his country, and describe minutely their characters, adding comparative notices of the species of each genus, will confer a great obligation on the lovers of science. Rafinesque has noticed a considerable number of animals of this order, some of them so peculiarly striped that they could not easily be mistaken were they to come under the observation of another zoologist; but in the instances in which his animals have been traced he is found to be so often inaccurate, and his generic characters are so generally imperfect, that science would sustain little loss if his notices were expunged from our books of natural history, were it not that they serve the purpose of inducing search in the localities he points out. In the preceding list we have omitted most of the doubtful species which have been admitted into the systems.

Sciurus cinereus, which has a multitude of synonyms tacked to it, inhabits most parts of the United States, being very abundant in Carolina and Pennsylvania. *Sc. rufiventer* of Geoffroy, *magnicaudatus* of Say, and *ludovicianus* of Curtis, quoted by Harlan, do not, as far as we can judge by the published descriptions, differ from certain states of *cinereus*. A *sc. hypoxanthus* occurs in Lichtenstein's list of Deppe's Mexican animals; but no character is given, so that we have no means of ascertaining in what respect it differs from the fulvous-bellied condition of *cinereus*. The *sc. capistratus*, or fox-squirrel, is a larger species, which varies greatly in its colours, and inhabits the middle and southern states of the Union: it is generally supposed to be one of the Mexican squirrels described by Hernandez, and named by some authors *variegatus*, but this wants confirmation. Say's *sc. grammurus* lives in holes, does not voluntarily ascend trees, and has very coarse fur; hence it is most probably a spermophile: it was found near the sources of the Arkansa. The black squirrels of the United States are generally referred to *capistratus*; but a smaller and totally black species (having no white muzzle) inhabits the northern shores of Lake Huron, and to this we have restricted the name of *niger* in the *Fauna Boreali-americana*. The larger black kind exists in Canada, and Hernandez mentions Mexican squirrels which are totally black, along

with others which are white with yellow tints. *Sciurus Colliæi* from California, figured in the appendix to Beechey's Voyage, differs from any species inhabiting the Atlantic states, but nearly agrees with Hernandez's account of the Mexican "*tlalmototli*". *Sc. Clarkii* and *Lewisii*, figured by Lieut.-Colonel Hamilton Smith in Griffith's Cuvier, were brought from the Missouri by the travellers whose names they bear. The latter is supposed by the editor of the work referred to, to be the *sc. annulatus* of Desmarest, whose native country was previously unknown. The *sciurus hudsonius*, named locally red-squirrel, or chickaree, the most northern American species, has a range from the arctic extremity of the woods to Massachusetts. Though destitute of cheek-pouches, it has been generally ranked as a tamias, perhaps on account of the dark line which occasionally divides the fur of the back from that of the belly; and, indeed, it resembles the *tamias* in forming burrows at the foot of the pine-tree, on which it seeks its food: it is evidently the *rubro-lineatus* of Warden, and probably the *ruber* of Rafinesque.

The *tamias Lysteri* ranges on the eastern side of the Rocky Mountains from the 50th parallel down to the Carolinas; it is the *tamias americanus* described by Kuhl (*Beitrage*, 69)*. Cuvier states, that the *t. striatus* inhabits both Asia and America; but we have met with no American animal that resembles Buffon's figure 10, 28, which Cuvier quotes. *T. quadrivittatus* inhabits the fur-countries, and goes southwards along the eastern declivity of the Rocky Mountains to the sources of the Platte and Arkansa. *T. buccatus* is a Mexican animal, which differs from the other admitted species of *tamias* in wanting longitudinal stripes and colours on the flanks. We cannot help surmising, therefore, that it may be a spermophile, for the two genera are very nearly allied, the only material difference in the dentition being, that the anterior molar of the upper jaw, which falls early in the true squirrels, but remains till old age in the tamias, is smaller in the latter than in the spermophiles. The typical species of each differ, indeed, a little in the feet; but *t. quadrivittatus* and *sp. lateralis* possess intermediate characters, which unite the two groups very closely, so that we may be prepared to find authors differing as to which genus or subgenus certain species ought to be referred. *Pteromys volucella* inhabits Canada, the United States, and, according to Lichtenstein, Mexico also. *Pt. sabrinus* and *alpinus*, which are not yet fully established as distinct from each other, and closely resemble the *volans* of Siberia, frequent the

* Fischer, *syn.*

forests of Canada, the Rocky Mountains, and the fur countries up to the 57th parallel.

The marmots are numerous in North America, particularly those which enter the subgenus *spermophilus*. These animals abound in the prairies, which are analogous to the Siberian steppes near Lake Aral, that are also overrun by spermophiles; but the only species that can be considered as common to the New and Old World is *guttatus* of North California and New Caledonia. This little animal is certainly so similar to the "souslik" of the Wolga, that the published figures or descriptions do not afford any distinctive marks; but no satisfactory comparison of specimens has yet been made. It is probable that Lichtenstein alludes to this species when he says, that there is a spermophile in Mexico which cannot be distinguished from the Siberian *citillus*: *guttatus* was considered by Pallas to be merely a variety of *citillus*. *Sp. Parryii* is the most northern species, being an inhabitant of the arctic coasts and the Rocky Mountains down to the 58th parallel. *Spermophilus lateralis* resides on the eastern declivity of the Rocky Mountains, from the 57th parallel down to the sources of the Arkansas. *Beecheyi* comes from Upper California, and *Douglasii*, which nearly resembles it, and is perhaps only a local variety, is from the adjoining district of the banks of the Columbia. *Franklinii*, *Richardsonii*, and *Hoodii* abound on the prairies of the Saskatchewan, the last ranging southwards to Mexico*, and being perhaps the Mexican squirrel of Seba, which is described as brown, with five or seven longitudinal whitish stripes. The *arctomys griseus* of Rafinesque, founded on Lewis and Clark's description of a Missouri animal, does not appear very different from *sp. Richardsonii*. *Sp. spilosus*, described by Mr. Bennett in the *Zoological Proceedings*, is from California. *Ludovicianus*, the "prairie dog" of the Missouri, has not been described as possessing cheek-pouches. *Arctomys empetra* frequents the woods of Canada and the fur countries up to the 60th parallel, while *monax* belongs to Maryland and the more southern Atlantic states. *A. brachyurus* is known only from Lewis and Clark's description of a Columbia river animal. The alpine districts of New Caledonia are the abode of a marmot named the "whistler", or perhaps more than one species is included under this trivial appellation, for the accounts given of it by the traders apply almost equally to the *pruinosus* of Pennant, the "tarpogan", or *caligatus* of Eschscholtz, and the *ochanaganus* described and figured by Mr. King in his recent

* Mexican specimens exist in the Museum at Frankfort. Dr. Ruppel.

narrative of Captain Back's journey. The latter animal agrees exactly with Eschscholtz's in the remarkable post-auricular black bar, in the general colour, and in the relative length of the fur on the different parts of the body, but differs in some minor points, and particularly in its smaller size, which may, however, be owing to its youth.

The only species of the restricted genus *mus* which is unequivocally indigenous to North America* is the *mus leucopus* of Rafinesque; and this so closely resembles *mus sylvaticus* of Europe that there are scarcely grounds for impugning the opinion of the older naturalists, who considered it to be the same species. In my dissections I did not succeed in detecting cheek-pouches, but Dr. Gapper has discovered cheek-pouches in a Canadian animal differing in no respect from it in exterior appearance, which he has therefore named *cricetus myoides*, and figured in the *Zoological Journal*. The *mus leucopus* is found everywhere, from the arctic circle down to the United States, and some authors state that it is common throughout the Union; but Dr. Harris says that it is not found in Massachusetts. It readily domesticates itself in the habitations of man, wherever the *mus decumanus*, *rattus*, and *musculus*, introduced from the other side of the Atlantic, have not penetrated. The *myoxus virginicus* of Reich, quoted in Fischer's synopsis, seems very closely allied to *mus leucopus*; it is an inhabitant of the foot of the Alleghanies. The *mus nigricans* of Rafinesque is supposed to be merely the common black rat (*rattus*).

The *meriones labradorius* inhabits America from the 60th parallel to an unascertained distance southwards. We have received several examples from different parts of the United States, and the *canadensis* of authors has not been proved to be a distinct species. Rafinesque indicates others, viz., *soricinus*, *leonurus*, *hudsonius*, *megalops*, and *sylvaticus*; but his notices are not sufficiently detailed for scientific purposes. Dr. Mitchell is equally vague in his account of a *meriones sylvaticus*.

Neotoma Drummondii abounds in the Rocky Mountains and *floridana* in Florida. As these animals resemble the *myoxi* in external form, it is desirable to know whether, like them, they are destitute of a cæcum. They build well-protected nests above ground, instead of burrowing like the meadow-mice, and appear to be omnivorous, like the common rat, than which they are even more destructive. Of M. Le Comte's *neotoma*

* A species inhabits Port Famine, in the Straits of Magellan, *mus magellanicus*. (King, *Zool. Proc.*, 1835.)

gossipina, which inhabits the southern states, we know no more than the name. The *sigmodon* hispidum* is found on the banks of the river St. John, which flows between Georgia and Florida. The *ferrugineum* inhabits cotton-fields on the Mississippi. *Fiber zibethicus* ranges from the Arctic Sea nearly to the Gulf of Mexico.

Though the various species of *arvicola* differ in size, aspect, and in the relative strength of their members, so as to be readily distinguishable from each other when brought into apposition, it is very difficult to frame specific characters by which they can be recognised when apart; and it is not therefore surprising that many nominal species should have been proposed, and, what is equally adverse to the interests of science, that many perfectly distinct animals should have been described under a common name. Until a revision of the genus has been accomplished, and American and European examples have been accurately compared with each other, we cannot admit that any one species is common to the two countries, as *amphibius* has been supposed to be. The majority of *arvicolæ* in our list belong to the fur-countries, though some, as *riparius* and *pennsylvanicus*, extend also far into the United States; the latter is the smallest as well as the most common American species. *A. rubricatus*, distinguished by a bright red stripe on the flanks, was seen by Mr. Collie in Behring's Straits†. The *georychi*, or lemmings, distinguished from the true meadow-mice by their thumb-nails and extremely short tails, all belong to the northern extremity of the continent, unless the very doubtful *spalax vittatus* of Rafinesque, found in Kentucky, shall be hereafter discovered to belong to this genus. The *mynomes pratensis* of Rafinesque requires further examination, as do also his *lemmus talpoides*, *albovittatus*, and *noveboracensis*, indicated rather than characterized in the *American Monthly Magazine* for 1820.

Though the "gauffres", or pouched rats, abound in all the prairie lands and sandy tracts of the United States, their history is still very obscure. The species, which are numerous, have been mostly confounded with the *tucan* of Hernandez or the *bursarius* of Shaw; but various generic names have been proposed, such as *geomys*, *pseudostoma*, *ascomys*, *diplostoma*, and *saccophorus*. The first figure of the Canada species published by Major Davies in the Linnean Transactions, represents the very large cheeks as filled from within and pendent externally,

* This genus requires further examination.

† *A. Nuttallii* appears in Dr. Harlan's list, but we do not know its distinctive characters nor its habitat.

slipping, as it were, from under the common integuments by a longitudinal slit, and having their surface covered with short hair. Cuvier, however, says of this figure, "*il n'y a rien de semblable dans la nature*", the true form, in his opinion, being that represented in the Transactions of the Berlin Academy, 1822–3, pl. 3, or in the *Fauna Boreali-Americana*, 18. B., where the pouches, running backwards under the integuments of the cheek, open externally on each side of the comparatively small true orifice of the mouth, producing the appearance which is alluded to in the generic appellation, signifying "false", or "double mouth". If the latter be the true form, the pouches can be filled and emptied only by the fore feet, which do not seem to be well calculated for such a purpose. Moreover, the late Mr. Douglas, whose ability as an observer no one will question, informed me that the pouches are filled from within the mouth by the action of the tongue, becoming, when fully distended, pendulous externally; but when empty being retracted like the inverted finger of a glove. Mr. Drummond also sent me several specimens of different species from various parts of the United States, some of them prepared with the empty pouches folded beneath the skin of the cheeks, and others with them filled and hanging down. Mr. Schoolcraft, on the other hand, has given a description of a gauffre from personal observation which corresponds with the view of the matter entertained by Cuvier. To reconcile these jarring statements, I adopted both of Rafinesque's genera, *geomys* and *diplostoma* in the *Fauna Boreali-Americana*; but since the publication of that work I have ascertained by the examination of a considerable number of specimens that the character of the dentition is the same in all; consequently they form but one genus, and Mr. Douglas's account of the cheek-pouches I now consider as well supported by the specimens I have examined. *Geomys borealis* inhabits the plains of the Saskatchewan, *Douglasii* and *bulbivorus* those of the Columbia; *bursarius* is from Canada, *pinetis* from Georgia, *talpoides* from Florida, *umbrinus* from Louisiana, *Drummondii* from Texas, and *mexicanus*, as its name imports, from Mexico. *Diplostoma fusca* and *alba* of Rafinesque were brought from the Missouri; but as the specimens were imperfect and the descriptions are equally so, they must be considered as doubtful*.

* Rafinesque characterized *diplostoma* as differing from *geomys* in the total absence of a tail, and in having only four toes on each foot; but Cuvier says that his specimens showed five toes, as in *geomys;* and it is very probable that the tails had been removed by the Indian hunters in preparing the skins. All the species that have come under our notice had short tapering tails,

Saccomys anthophilus of F. Cuvier has the teeth of *geomys*, but he has placed it in a separate genus on account of the supposed peculiarity of its pendent pouches; it is smaller than any *geomys* we have seen, and differs from all that we have enumerated in the greater length of its tail. The *cricetus fasciatus* of Rafinesque from Kentucky is probably either a *geomys* or *saccomys;* but if so, it is peculiar in having ten transverse black streaks on the back, if indeed this appearance was not produced, as is sometimes the case, by cracks in mounting the skin. *Apluodontia leporina* inhabits New Caledonia and the banks of the Columbia, where its skins are used for clothing, and form an article of traffic.

The beaver ranges on the eastern side of the continent, from the most northern woods down to the confluence of the Ohio with the Mississippi; and it would appear, from a remark of Dr. Coulter's, that on the western side it descends in the neighbourhood of the Tule lakes to the 38th parallel. The purpose served in the economy of the animal by the castoreum and a fatty substance deposited in the adjoining sacs has not yet been made out. The Canada porcupine (*erethizon dorsatum*) inhabits the country lying between the 37th and 67th parallels. The *hoitzlacuatzin* of Mexico is identified by Lichtenstein with the *synetheres prehensilis**, we do not know with what propriety; but if he be correct, it is, if not a solitary instance, at least very nearly so, of a rodent animal being common to North and South America. The spotted cavy (*cœlogenys*) and perhaps a species of *cavia* and one of *dasyprocta* extend from South America to the West Indies and Mexico; but in other respects the animals of this numerous order differ greatly in the zoological provinces of North and South America.

The most northern American hare is *lepus glacialis*, which

thinly clothed with very short whitish hairs. The incisors are differently grooved in different species. *Geomys bulbivorus* and *umbrinus* have these teeth quite smooth; *borealis* and *talpoides* have a very fine groove close to the inner margin of each upper incisor; *Douglasii* has fine submarginal grooves on all the incisors, viz., next to the inner edges of the upper ones and the outer edges of the under ones; *bursarius* and *Drummondii* have a deep rounded furrow in the middle of the anterior surface of the upper incisors, in addition to the fine inner submarginal one. The under incisors are quite plain in *Drummondii*, and most likely in *bursarius*, also, as no mention is made of their being grooved. In all these species the auditory opening is scarcely perceptibly elevated. *Geomys* or *ascomys mexicanus* of Lichtenstein has short round ears, with a single central furrow in the upper incisors. A variety of this is mentioned in Fischer's synopsis. They are inhabitants of the Mexican uplands, where they lay waste the maize-fields.

* The island of Cuba nourishes another kind of rodent animal with a prehensile tail, named *capromys*.

frequents the islands of the Arctic Sea, the barren grounds, and the Rocky Mountains, down to the 60th parallel. *L. americanus* inhabits the woods from the Gulf of Mexico to their northern limits. *L. virginianus* is found on the prairie lands of the Saskatchewan and Missouri, and it is said also on the Blue Mountains of Pennsylvania; but further investigations are requisite to prove the existence of the same species in such different localities. A "marsh hare" from the southern parts of the United States has been recently described in the *Zoological Proceedings*, and it may be this that Dr. Harlan has associated with the prairie hare under the name of *virginicus*. *Lepus mexicanus* is the name bestowed by Lichtenstein on the "citli" of Hernandez, and *cunicularius* that by which he designates the "tochtli". How far either of these species ranges northwards, or whether they have been compared with the Florida marsh hare we know not. *Lagomys princeps* has its abode on the crests of the Rocky Mountains, where it is probable that other species will be hereafter detected. Lichtenstein tells us that cavys are common in Mexico, and some authors have stated that the common agouti (*dasyprocta acuti*) inhabits the southern extremity of the United States; but F. Cuvier has separated the latter animal by the specific appellation of *carolinensis*. The *lipura hudsonica* of Illiger, or *hyrax hudsonius* of Shaw, must be excluded from the American fauna until we receive satisfactory evidence of its origin.

Ord. EDENTATA.

Dasypus hybridus, DESM.

This small order may be called South American, the whole of the animals composing it belonging to that country, except three or four African or Indian species comprised in the genera *oryctopus* and *manis*. Lichtenstein, at the close of some remarks on the "ayo-tochtli" of Hernandez, says, that the specimens brought home by Deppe accorded exactly with the *tatou mulita* of Azzara, which Cuvier refers to the *dasypus 7-cinctus* of Linnæus. By others the *ayo-tochtli* is considered to be the *d. peba* of Desmarest, and we also find the *mexicanus* of Brisson ranked among the synonyms of *d. Encoubert* of Desmarest. The latter author informs us that the *hybridus* is common in Paraguay and on the Brazilian pampas. It is the only example of an animal of this order that has been ascertained to enter the North American fauna, though Lichtenstein conjectures that a *myrmecophaga* may also be found in Mexico, namely, the *atzca-coyotl* or *tlal-coyotl* of Hernandez.

Ord. PACHYDERMATA.

Dicotyles torquatus, Cuv.

This order is at once remarkable for the magnitude of the animals composing it, the great proportion of extinct species, and the small number which now exist in the New World. Two genera only, comprising four or five species, are known in America, namely, *tapir* and *dicotyles*, both of which belong to the southern zoological province: yet there is one species, the common peccari or *dicotyles torquatus*, which ranges northwards to the Red River, a tributary of the Mississippi, where it was observed by Nuttall; this is probably the *coyametl* of Hernandez. Dr. Harlan states that the tapir is also an inhabitant of Mexico, without quoting his authority; but Dr. Roulin, who has written a very learned and elaborate treatise on this animal, and figured a second American species, is of opinion that the *tapirus americanus* ranges from the 35th degree of south latitude only to the 12th north, while the new species, *t. pinchachus*, is confined to the higher Cordilleras of the Andes, and does not advance further to the north than the 10th degree. The very remarkable resemblance between the scull of the Indian tapir and that of the *palæotherium* has been pointed out both by Cuvier and Dr. Roulin.

Fossil elephants and mastodons occur in North America, and though the present stock of horses, wild and tame, in that country are believed to have had an European origin, fossil bones of horses were found by Captain Beechey under the cliffs of Kotzebue Sound mixed with those of elephants and other animals. There is a considerable resemblance in the kinds of quadrupeds found in the *eocene* gypsum quarries of Paris, named in Cuvier's list—bat, large wolf, fox, coatis, raccoon, genette, dormouse, and squirrel—to those now existing in Mexico. The genette may be represented in tropical America by *bassaris* or *gulo barbara*, and the dormouse by *neotoma;* while the *palæotherium* and other extinct *pachydermata* of Montmartre are allied to the tapir. The other genera are American, but *dicotyles* and the *felidæ*, which form so conspicuous a part of the existing carnivora, do not occur in Cuvier's list.

Ord. RUMINANTIA.

Cervus alces*?, L. Griff. *Cuv. pl.*
„ tarandus*, L.? Edw. 51.
„ strongylocerus, Schreb. 247.
„ macrotis, Rich. *F.B.A.* 20.
„ virginianus, Buff. 12, 44.
„ mexicanus, Gmel. Griff. *Cuv.*
„ leucurus, Dougl. Rich. *F.B.A.*
Cervus nemoralis, H. Smith, Griff. *Cuv.*
Dicranocerus furcifer, Rich. *F.B.A. pl.*
Capra americana, Rich. *F.B.A.*
Ovis montana*?, Id. *l.c.*
Bos americana, Griff. *Cuv. fig.*
„ moschatus, Penn. *Arct. Zool.*

Only two species of this order are common to the old continent and America, and these have the highest northern range, namely, *Cervus alces* and *tarandus*. If the *ovis montana* be, as Cuvier hints, the same with the Siberian argali, it is a third common species. The North American deer are still very imperfectly known, and a revision of the species would well repay the labour of a naturalist who has an opportunity of seeing them in a state of nature; the deer of the Pacific coast in particular require investigation, as they are known only by imperfect descriptions, no figures of them having been published nor specimens brought to Europe*. The reindeer is the most northern ruminating animal, being an inhabitant of Spitzbergen, Greenland, and the remotest arctic islands of America. On the Pacific coast it descends as low as the Columbia river, being, however, much less common there than in New Caledonia. On the Atlantic it exists as far south as New Brunswick, while in the interior its southern limit is the Saskatchewan river. The different varieties of reindeer ought to be compared with each other, and detailed dissections of the American kinds are still wanted. The southern range of the elk is the Bay of Fundy, on the eastern coast, though it is said to have existed formerly as far south as the confluence of the Ohio and Mississippi; but this report is rendered uncertain by the name elk having been applied in different parts of the country to different kinds of deer. It frequents all the wooded districts up to the mouth of the Mackenzie, in the 68th degree of latitude, but very seldom appears in the prairies or barren grounds. The wapiti, or *cervus strongyloceros*, does not travel to any distance from the prairie lands, on both sides of the Rocky Mountains, and not further north than the 54th parallel. *C. macrotis* and *leucurus* frequent the prairies of the Saskatchewan and Missouri, and, according to report, the west side of the Rocky Mountains also. *C. virginianus* is found from Canada to the Gulf of Mexico; *nemoralis* and *mexicanus* inhabit the latter country, the former going southwards to Surinam†. The *antilope furcifer* abounds on the prairies of the Missouri, Saskatchewan, and Columbia, and is believed to range southwards to Mexico. It differs much

* The following is a list of the deer of Columbia and New Caledonia furnished to me by P. W. Dease, Esq., of the Hudson's Bay Company: moose-deer (*c. alces*); rein-deer (*c. tarandus*); red-deer, or wawaskeesh (*c. strongyloceros*); *kinwaithoos*, or long-tailed deer; mule-deer; jumping-deer, or cabree; fallow-deer, or chevreuil. The specific names of the last four have not been satisfactorily ascertained. The *antilope furcifer* is named white-tailed cabree to distinguish it from the jumping-deer, in which neither the tail, nor the rump, is white.

† Lieut.-Colonel H. Smith, in Griffith's Cuvier.

from the true antelopes, and, if it be considered as belonging to a distinct genus (*dicranocerus*), it is the only generic form of this order found in North America which does not exist also in Europe, unless a second be found in *ovibos moschatus*, separated from *bos*. The *capra americana* and *ovis montana* inhabit the Rocky Mountains from Mexico to the northern extremity of the range, and also the maritime Alps of California and New Caledonia, the former confining itself to the higher ridges. The musk-ox is peculiar to the barren lands, travelling in summer over the ice to Parry's Islands; but though it has this high range, it does not exist either in Asia or Greenland. The chief residence of the bison (*bos Americanus*) is on the prairie lands, east of the Rocky Mountains; it frequents the woods also up to the 62nd parallel, but nowhere approaches within 600 miles of Hudson's Bay. Though this animal is at present rarely ever seen to the eastward of the Mississippi, it is said to have formerly frequented Pennsylvania and Kentucky, but the authority for its ever having ranged to the Atlantic coast is by no means good. It does not exist in New Caledonia, though it has crossed the eastern crest of the Rocky Mountains further south, to the headwaters of the south branch of the Columbia; but even in that latitude it does not advance towards the coast, a spur of the Californian Alps* (or "a counterfort" connecting them with the Rocky Mountains), which skirts the Snake River, or south branch of the Columbia, offering apparently an effectual barrier to its further progress westward. In the fur countries it does not go to the eastward of the 97th meridian†.

Ord. CETACEA.

As the cetacea traverse the depths of the ocean in pursuit of their prey, it is highly probable that many species are common to the same parallels of the New and Old World. Those that frequent the Greenland seas are at least entitled to be enumerated among the animals both of Europe and America; and in like manner the *cetacea* of the North Pacific and sea of Kamschatka are common to the latter country and to Asia; but the animals of this order are so imperfectly known that we cannot give the correct geographical distribution of even a single species.

* Named the "Blue Mountains".

† Horned cattle thrive well in America. They were introduced into Upper California about 70 years ago, and in 1827 the Missions, according to Dr. Coulter, possessed upwards of 300,000 head, 60,000 being annually slaughtered to keep down the stock. They are multiplying also very fast on the banks of the Columbia, where they have lately been introduced by the Hudson's Bay Company.

Dr. Harlan enumerates fourteen of the true cetacea as having been detected on the coasts of North America; but on correcting his list, and striking out the synonyms agreeably with the indications in the *Règne Animal*, the number is reduced to ten. Of the herbivorous cetacea two at least enter the North American fauna, viz., the *stellerus borealis*, or *rytina*, which belongs to the Sea of Kamschatka, and a manatee, that frequents the mouths of rivers in East Florida. This species has been named *latirostris* by Dr. Harlan; but Temminck observes that it is "*tres douteuse*," meaning thereby, we suppose, that it is not distinct from one of the ascertained species, *senegalensis* or *americanus*; the latter, which inhabits the tropical coasts, is supposed to go as far north as Mexico.

The following list comprises the cetacea which are enumerated in the *Règne Animal*, Desmarest, Fischer's synopsis, &c., as extending their range to America; but nothing is less certain than their identification with European species bearing the same names.

Manatus americanus, CUV.
„ *latirostris*, HARLAN.
*Rytina borealis**, *Nov. Act. Petr.* 13, 13.
Delphinus delphis*, LACEP. 13, 1.
„ tursio*, HUNT. *Ph. tr.* 1787, 18. (*nisarnac*, FABR.)
„ *canadensis*, DUHAMEL, 2, 10, 4.
Phocæna gladiator*, LACEP. 15, 1.
„ communis*, ID. 13, 2.
„ *intermedia*, HARL. *Ac. Sc. Ph.* 6, *fig.*
Delphinapterus leucas*, SCORESB. 14.
Hyperoodon Dalei*, HUNT. *Ph. tr.* 77, 19.
„ *anarnichum**, FABR.
Monodon monoceros*, SCORESB. 15.
Physeter macrocephalus*, LACEP. 10.
„ tursio*, Bayer, *Nov. Act. Cur.* 3, 1.
Balæna mysticetus*, SCORESB. 12.
„ *nodosa*, BONNAT.
„ physalis*, ID. 2, 2.
„ boops, ID. 3, 2.

Chamisso, in the *Mem. de la Soc. Leopold*, &c., v. 12, has described nine cetaceous animals which frequent the Aleutian islands, founding his species on the figures and reports of the natives. (Vide Less. *Man.*)

We shall conclude our cursory remarks on the *mammalia*, with a list of the most northern species.

Cetacea.
Monodon monoceros. 81¾° N. lat.
Calocephala fœtida. 82¾° N.
Phocæ aliæ.
Trichechus rosmarus. 80¾° N.
Ursus maritimus. 82½° N.
Vulpes lagopus.
Cervus tarandus.
Georychus Hudsonius.
Mustela —— ? } 80° N.
Gulo luscus.
Lupus occidentalis.
Lepus glacialis.
Bos moschatus. } 75° N.
Mustela erminea. 73½° N.
Georychus grœnlandicus. 71° N.
Ursus arctos ?
Lutra lataxina.
Georychus trimucronatus.
Arvicola rubricatus. } 70° N.
Sorex palustris.
„ Forsteri.
Vespertilio —— ?
Lepus americanus.
Fiber zibethicus.
Cervus alces. } 67° or 68° N.
Felis canadensis. 66° N.
Didelphis virginiana. 44° N.
Dicotyles torquatus. 31° N.
Dasypus hybridus.
Pedimana. } *Mexico.*

The species noted as reaching the 80th, or a higher parallel, have been observed on Spitzbergen or in the neighbouring seas. We are not aware of any rodent animal having been taken alive in so high a latitude, but the skeleton of a Lemming was found on the ice in 81¾° N. by Sir Edward Parry on his memorable expedition to the northward of Spitzbergen. The same species exists on the most northern American Islands, and some small gnawers might have been supposed to inhabit Spitzbergen from a *mustela* having been seen there by Captain Phipps's people. (*Voyage towards the North Pole in* 1773, p. 58.) The North Georgian or Parry's islands support those marked as reaching 75° N. with the addition of all the Spitzbergen species, except the weasel. We thus see that the orders *carnivora, rodentia, ruminantia* and *cetacea*, are represented in the most northern known lands or coasts, the *felidæ* reach 66° N., the *marsupiata* 44° N., the *pachydermata* 31° N., and the *edentata* and *quadrumana* to Mexico.

The following table exhibits the number of North American mammalia belonging to each order, and two tables, extracted from Fischer's synopsis, are inserted in a note to furnish the means of comparison; but it is to be observed that Fischer admits many species which still require much elucidation before they can be fully established. Temminck considers that there are about 930 well-determined species of *mammalia*, and 140 doubtful ones. If this estimate be nearly correct, North America nourishes about one-fifth of the known species.

Note.—An (*) *is prefixed to the species whose identity with those of Europe bearing the same names is not fully ascertained.*

Orders, or Families.	Total number of species.	Proper to N. Amer.	Common to other countries.
Carnivora	101		
Cheiroptera	......	17	
Insectivora	......	11	
Carnivora	......	38	2 *7
Amphibia	......	12	11
Marsupiata	......	3	
Rodentia	71	70	*1
Edentata }	......	2	
Pachydermata }	16	1	
Ruminantia }	......	10	*3
Cetacea	19	5	14
Total	207	169	27 *11

AVES.

The *birds*, having always been objects of interest to collectors and artists, are better known than the other animal productions of North America. Edwards at an early period figured thirty-eight species from Hudson's Bay; the natural history appendices to the recent arctic voyages contain full lists of those which frequent the sea-coasts in the higher latitudes, and the second volume of the *Fauna Boreali-Americana* has made known some new species, which, migrating through the great central valleys of the Mississippi and Mackenzie, or crossing the Rocky Mountains from California, had escaped the notice of the ornithologists of the eastern states*. Good lists are still wanted of the Labrador and Canadian birds, and also local cata-

* *Note.—An (*) is prefixed to the doubtful species.*

Ordines et Familiæ in Europa.	In toto.	Proprie.	Cum aliis terris.
Quadrumana	1	......	1
Carnivora			
Cheiroptera	22 *7	18 *7	4
Insectivora	16 *3	10 *3	6
Carnivora	28 *1	3 *1	26
Amphibia	12 *4	4 *4	7
Rodentia	40 *4	9 *4	31
Edentata	......	......	...
Pachydermata	3	......	3
Ruminantia	14	1	13
Cetacea	20 *3	6 *3	14
	156 *22	51 *22	105

Ordines et Familiæ.	Orbis priscus.			America.			Polynesia.			Patria ignota.
	In toto.	Proprie.	Cum aliis terris.	In toto.	Proprie.	Cum aliis terris.	In toto.	Proprie.	Cum aliis terris.	
Quadrumana	78 *20	78 *20	...	68 *12	68 *12	...	...	...	...	2 *5
Carnivora / *Cheiropt., Feræ, Bestiæ*	256 *35	225 *31	28 *3	171 *68	140 *64	31 *4	52 *9	45 *8	7 *1	19 *3
Rodentia (*Glires*)	151 *15	144 *15	7	106 *27	99 *27	7	2	2	...	1
Eden., Pachyd., Rumin. / *Bruta, Belluæ, Pecora*	146 *10	144 *10	2	34 *12	32 *12	2	3	3	...	1 *1
Cetacea	45 *3	35 *3	9 3	21 *5	7 *5	14	11 *2	2 *2	9	2 *2
	676 *83	626 *79	46 *6	400 *124	346 *120	54 *4	68 *11	52 *10	16 *1	25 *11

* The natural history of Sir John Ross's first voyage, Sir Edward Parry's third and fourth voyages, Sir John Franklin's first journey, and Captain Back's recent one accompany the respective narratives. Sir Edward Parry's first

logues for various districts of the United States, to contribute towards our knowledge of the geographical distribution of the species; but with regard to the discovery, description, and illustration of the feathered tribes of that country comparatively little remains to be accomplished. When Wilson's admirable work appeared, European ornithology could boast of nothing equal to it*. The Prince of Musignano's highly valuable critical examination of synonyms†, and his publication of new species‡, ably supply what Wilson, cut off in the midst of his career, left incomplete; and the magnificent book of Audubon, now in the course of publication, surpasses every attempt of the kind in any country. Audubon's plates present to us some of the finest specimens of art, and his ornithological biographies convey the observations of a whole life enthusiastically devoted to studying the forms and habits of the feathered inhabitants of the air. It is announced that his forthcoming volume will contain a synopsis arranged in conformity with the recent improvements of science, and also a treatise on the geographical distribution and migration of the species; in short, this grand work will henceforth be the standard of reference for the birds which frequent the Atlantic states from Labrador to the Gulf of Mexico, and eastward to the great prairies.

Of the birds of Russian America and California we have only detached notices by travellers, the Appendix to Capt. Beechey's voyage by Mr. Vigors containing the only scientific list. Upwards of sixty species are therein noticed; but it is to be lamented that the collectors have in many instances omitted to record the places where the specimens were procured, so that even their country is in some instances doubtful§. Lichtenstein's promised Mexican fauna, if it be published, has not yet reached this country, and there is no other work to which we can look for a full enumeration of Mexican birds. One hundred species, however, from that country were character-

and second voyage, and Sir John Ross's second voyage have the natural history appendices published in separate quarto volumes; while the *Fauna Boreali-Americana*, of which three volumes have been published, is intended to supply the place of an appendix to Sir John Franklin's second journey. The appendix to Captain Beechey's voyage, though mostly printed off several years ago, is not yet published.

* Vieillot's "*Oiseaux de l'Amer. septentr.*," Paris, 1807, preceded Wilson's book, but only two volumes have appeared.

† Observations on the nomenclature of Wilson's Ornithology, *Journ. Ac. Sc. Phil.*, iii. *et infra*, 1823.—Genera of North American birds, &c., *Lyc. of Nat. Hist.*, New York, ii. 1826.—Catalogue of birds of the United States, *Maclurian Lyc.*, No. i. Phil., 1827.

‡ Continuation of Wilson's Ornithology, V. Y., 2 vols.

§ Since this report was read, we learn that Professor Nuttall has returned from Upper California with a rich harvest of objects of natural history, and among the rest with thirty species of undescribed birds, which will be included in Audubon's work.

ized by Mr. Swainson in the *Philosophical Magazine* for 1827, and upwards of one hundred and thirty named by Lichtenstein appear in the sale-list of duplicates of the collection made for the Berlin Museum by Herren Deppe and Schiede. As the authors of these two lists do not appear to have been aware of each other's labours, some of the species are probably twice named; and as we have no means of knowing whether many of these Mexican birds pass the tropic, or at least frequent the elevated table-lands, so as properly to enter the North American fauna, all their names are put in italics. The other parts of the lists have been compiled chiefly from Audubon's work; and that I might be enabled to refer to the species which will be comprised in the fourth volume, he has obligingly furnished me with a list of the plates which it will contain. Additions are made from the other works already quoted. The arrangement adopted is that proposed by Mr. Vigors, with Mr. Swainson's alterations, The extreme range of each species as far as ascertained is noted, and the birds which have been actually detected in Mexico or California are distinguished by abbreviations of the names of these countries.

The similarity of the North American ornithology to that of Europe is evinced not only by the identity or close resemblance of the generic forms, but also by a third part of the species being common to the two *faunæ*. Europe is visited by a few of the *meropidæ*, *promeropidæ*, and *struthionidæ*, families which have no members in North America; the *muscicapidæ*, represented in Europe by four species, which go pretty far north, furnish to the American fauna only the *todus viridis* and *psaris cayanus*, which do not ascend higher than Mexico; but this family is amply replaced in America by the *tyrannulæ*, which, though arranged by Mr. Swainson as part of the *laniadæ*, were considered by previous writers as fly-catchers, and scarcely to be separated from the Linnean genus *muscicapa*. North America, on the other hand, enumerates in its fauna certain families not found in Europe, viz., the *trochilidæ*, *psittacidæ*, *rhamphastidæ*, and *trogonidæ*, but none of the two latter groups go so far north as to reach the parallel of the south of Europe. The subjoined table has been constructed to show at a glance the chief points of agreement or difference between the two faunæ, the terms of comparison being assimilated by the omission of the American species which do not attain the 36th parallel of latitude. The number of species which compose the corresponding groups of each fauna often coincide remarkably, and this occurs even in families which have few or no species common to each country. There is a discordance with this remark observable in some families of *dentirostres*, which is perhaps owing to my imperfect arrangement of the species. The agreement between the faunæ is greatest among

the *grallatores* and *natatores*, two thirds of these orders being common to the two, while in the aggregate of the other orders only between one sixth and one seventh are common. As both the waders and water-birds are very migratory, we might be induced to infer that it is from this cause that so many of them are identical on both sides of the Atlantic, but on investigating the habits of the species, we find that several which do not migrate at all, exist in every quarter of the globe, and some owls, which are the most resident birds of prey, inhabit very many distant countries without any appreciable change of form in the species.

Names of Families.	Number of species. In America from 36° N. northwards.	Number of species. In Europe.	Common to both Countries.	Names of Families.	Number of species. In America from 36° N. northwards.	Number of species. In Europe.	Common to both Countries.
Vulturidæ	3	4	...	Promeropidæ	...	1	...
Falconidæ	24	28	10	Trochilidæ	3	...	...
Strigidæ	14	15	9	Columbidæ	3	4	...
Laniadæ	19	5	1?	Phasianidæ	1	1	...
Merulidæ	14	18	3	Tetraonidæ	15	17	3
Sylviadæ	63	75	4	Struthionidæ	...	3	...
Ampelidæ	9	1	1	Tantalidæ	4	1	1
Muscicapidæ	...	4	...	Ardeidæ	11	11	4
Fringillidæ	56	54	8	Scolopacidæ	40	38	24
Sturnidæ	10	3	...	Rallidæ	7	8	1
Corvidæ	10	14	3	Charadriadæ	12	12	6
Picidæ	15	9	2	Anatidæ	40	36	25
Psittacidæ	1	...	...	Colymbidæ	7	8	6
Cuculidæ	2	3	1	Alcadæ*	7	7	7
Certhiadæ	11	6	1	Pelecanidæ	8	6	5
Hirundinidæ	7	7	2	Laridæ	39	38	33
Caprimulgidæ	3	2	...				
Halcyonidæ	1	2	...	* Eight species frequenting the Sea of Kamschatka are excluded.			
Meropidæ	...	2	...				

Obs.—In the following lists species which are common to Europe and America are marked by an *. The range is denoted by degrees of latitude. The references are to plates, and the following abbreviations are used :—

Col., Planches coloriées, Temminck, &c.—*Enl.*, Planches enluminées, &c.—A., *American Ornithology*, by Audubon, &c.—Vig., *Ornithological Appendix to Capt. Beechey's Voyage*, by N. A. Vigors, Esq.—King., *Birds of Patagonia, Zool. Journ.*, by Capt. King, &c.—Sw., Swainson, *Phil. Journ.*—Licht., *Deppe's Sale-List of Birds, &c., Berlin.*—F.B.A., *Fauna Boreali-Americana.*—*Cal.*, *California.*—*Mex.*, *Mexico*, &c.

Mr. Swainson's five genera of *falconidæ* are *falco, accipiter, aquila, cymindis,* and *buteo*, corresponding to the groups denoted by brackets in the succeeding table; and of his five genera of *strigidæ*, the two first, *strix* and *asio*, are indicated by brackets; and the three aberrant ones, *nyctea, nyctipetes,* and *surnia,* are each represented by a single North American species.

Sub-typ., order RAPACES. *Sub-typ. fam.* VULTURIDÆ.

Sarcoramphus gryphus, *col.* 103, *Mex.* 35° S.—31° N. BON.
,, papa, *enl.* 428. *Mex.* LICHT. 30° S.—30° N. BON.

Cathartes jota, A. 106. *Mex.* 35° S.—48° N. (*atratus.*)
,, aura, A. 151. *Mex.* 20° S.—54° N.
,, californianus, SHAW, *Nat. Misc.* 301 25° N.—49° N.

Typ. fam. FALCONIDÆ.

Falco peregrinus*, A. 16. 54° S.—74° N.
,, islandicus*, A. 196. 54° N.—74° N.
,, æsalon*, F.B.A. 25. ?—54° N.—?
,, columbarius, A. 92. 25° N.—65° N.
,, temerarius, A. 85. ?—40° N.—?
,, sparverius, A. 142. 54° S. KING.—54° N.
,, *aurantius*, LATH. 5° N.—*Mex.* LICHT.
,, *anthracinus*, LICHT. *Mex.*

Ictinea plumbea, A. 117. 2° N.—35° N. (*mississipiensis*, WILS.)
Accipiter velox, A. 364. *Mex.* LICHT.—51° N.
,, *fringilloides*, VIG. *Mex.*
,, *mexicanus*, SW. *Mex.*
,, Cooperii, A. 36. 29° N.—40° N. (*Stanlei.*)
,, lineatus, A. 56. 35° N.—57° N.
,, hyemalis, A. 71. 29° N.—57° N. ?
Astur palumbarius*, A. 141. 29° N.—68° N. (*atricapillus.*)
,, pennsylvanicus, A. 91. 31° N.—46° N.
,, borealis, A. 51. *Mex.* SW. *Cal.* VIG.—58° N.
,, *nitidus*, *col.* 87, 1. 2° N.—*Mex.* LICHT.
,, *magnirostris*, *enl.* 46. 30° S.—*Mex.* LICHT.

Pandion haliæetus*, A. 81. 5° N.—60° N. (*americanus*, SW.)
Haliæetus leucocephalus*, A. 31 and 126. *Mex.*—62° N.
,, Washingtonii, A. 9. *Kentucky.* 38° N.
Aquila chrysäeta*, A. 181. 36° N.—66° N.
Harpya imperialis, GRIFF. *Cuv.* 25° S.—*Mex.* SW.
Morphnus maculosus, VIEILL. 3. *Mex.*

Polyborus brasiliensis, A. 161. 54° S.—23½° N.
Elanus dispar, A. 352. 25° S.—35° N.
Nauclerus furcatus, A. 82. *Peru.*—38° N.

Buteo vulgaris*, F.B.A. 27. *Mex.* SW. *Cal.* VIG.—58° N.
,, Harlani, A. 86. 30° N.—? N.
,, lagopus*, A. 166. 35° N.—68° N.
,, *pterocles*, *col.* 59. 25° S.—*Mex.* SW.
Circus cyaneus*, A. 356. *Mex.* SW.—68° N.
,, *rutilans*, *col.* 25. 25° S.—*Mex.* SW.

Aber. fam. STRIGIDÆ.

Strix flammea*, A. 171. 20° N.—44° N.
,, nebulosa*, A. 46. 30° N.—53° N.
,, otus*, F.B.A. 40° N.—60° N.
,, mexicana, VIEILL. 20. *Mex.* 25° S.—*U.S.* BON.
,, brachyotus*, A. 372. 25° S.—67° N.
,, Tengmalmi*, A. 375. 54° N.—60° N.
,, *acadica*, F.B.A. 39° N.—50° N.
,, cinerea*, A. 351. 42° N.—68° N. (*lapponica.*)

Strix virginiana, A. 61. 52° S.—68° N.
,, arctica*, F.B.A. 30. ?—54° N.—? (*scandiaca* ? L.)
,, asio, A. 97. 30° S.—45° N.

,, nyctea*, A. 121. 31° N.—75° N.

,, cunicularia, A. 394. 40° S.—40° N.

,, funerea*, A. 362. 39° N.—68° N.

The generic or subgeneric raptorial forms which are peculiar to America are *sarcoramphus*, *cathartes**, *ictinia*, *morphnus*, and *polyborus*: some species of *harpya* and *elanus* inhabit Africa, one of them, *el. melanopterus*, occasionally appearing in the south of Europe. A group of owls, named *nyctipetes* by Mr. Swainson, is also African, one species only being North American, viz., *cunicularia*, or the singular burrowing owl of the prairies. With respect to the distribution of species, no American vulture is common to both sides of the Atlantic, and they all belong more properly to the tropical fauna, being (with the exception perhaps of *cathartes californianus*) merely summer visitors to the north. Indeed, as their food is carrion, their utility in the economy of nature is obviously greatest in the warmer latitudes, where they accordingly abound: none of them go beyond the 54th parallel, and they reach that latitude in the interior prairies only, where the summer-heat is considerable. One European vulture (*fulvus*) ascends to the 51st degree of latitude in Silesia, and another (*percnopterus*) has been occasionally killed in England. Nearly one third of the American *falconidæ* belong also to Europe; several of them, as may be seen by inspecting the preceding table, range from one end of the New World to the other, and some, as *falco peregrinus*, *pandion haliæetus*, *aquila chrysaëta*, and *circus cyaneus*, may be said to be cosmopolites. Three of these widely-spread species are types of three of the five generic groups into which Mr. Swainson divides the family. The common buzzard of the fur-countries is identical with the European one; but its winter quarters in America are on the coast of the Pacific, hence it has not hitherto been enumerated among the birds of the United States. *Elanus dispar* so closely resembles *melanopterus* of Africa and southern Europe, that the Prince of Musignano hesitates to agree with Temminck in pronouncing them to be distinct. On the other hand, the goshawk of the New World, though considered by some ornithologists as identical with the European one, is judged by Mr. Swainson to be a peculiar species, for which Wilson's appellation of *atricapillus* ought to be retained; the differences of their plumage are pointed out in Sir William Jardine's edition of Wilson. In the same work, the *nauclerus furcatus* is recorded as having been killed in England. On the authority of the Prince of Musignano, also quoted there, we have considered the *accipiter Stanlei* of Audubon as identical with *Cooperii*. The owls, as we have already noticed, though much less mi-

* *Cathartes*, or *neophron percnopterus*, of the European fauna, is considered by Mr. Swainson to be only a subgeneric form of *vultur*.

gratory than either the vultures or falcons, are even more widely diffused. Two thirds of the North American species are found in Europe, and *flammea, otus,* and *brachyotus,* all belonging to the typical genus, are spread over the whole world. As in the case of the *falconidæ,* the species entering the subtypical generic group are mostly confined to particular countries, while the aberrant genus *nyctipetes,* like *cymindis,* is mostly South American, one species only (*cunicularia*) extending from the 40th degree of south latitude by the valley of the Mississippi, to an equal degree north of the equator. Though the American ornithologists have all considered their *strix otus* to be actually the same with the European species, Cuvier says that the one figured by Wilson, 51, fig. 3, (and 19, fig. 1, young), is different, while he considers the *mexicana* (*clamator,* Vieill., *longirostris,* Spix,) to be merely a dark variety of the European bird*. *Strix cinerea* of Latham, Bonaparte, and the *Fauna Boreali-Americana* is identified by Temminck with his *lapponica.*

Typ. ord. INSESSORES.

Sub. typ. tribe, Dentirostres.

Fam. LANIADÆ.

Lanius ludovicianus, A. 57. *Mex.* LICHT. Sw. *Cal.* VIG. 23° N.—38° N.
„ excubitor*, A. 192. 32° N.—60° N.
„ excubitorides, F.B.A. 34. ?—54° N.
„ elegans, F.B.A. ?—50° N.
„ nootka, LATH. ?—50° N.
Thamnophilus canadensis, enl. 479. 2. *Canada*? ? (*turdus cirrhatus,* GM.)
„ *doliatus, enl.* 297. 2. 2° N.—*Mex.* LICHT.
Hypothymis mexicana, LICHT. *Nov. Gen.*
Saurophagus sulphuratus, enl. 296. 25° S.—Sw. LICHT.
Ptiliogonys cinereus, Sw. *Table l. Mex.*
„ *nitens,* Sw. *Mex.*

Tyrannus intrepidus, A. 79. *Mex.* Sw.—57° N.
„ borealis, A. 174. 38° N.—53° N.
„ dominicensis, A. 170. *Mex.* Sw. 20° N.—35° N.
„ cinereus, VIG. *Cal.* 36° N.—38° N.
„ crinitus, A. 129. 23° N.—42° N.
„ verticalis, A. 398. *Arkans.* 36° N.
„ *ferox, enl.* 571. f. 1. 2° N.—*Mex.* LICHT.
„ *crassirostris,* Sw. *Mex. table l.*
„ *vociferans,* Sw. *Mex.*
Milvulus savannus, A. 168. 2° N.—40° N.
„ forficatus, A. *App. Mex.*—34° N.

* Though many foreign owls, and, among others, four Australian ones, *castanops, personata, cyclops,* and *delicatulus,* of Gould, were formerly confounded with *flammea,* causing it to be considered as quite a cosmopolite, its range is actually very extensive, there being no difference, according to Temminck, in the species as existing throughout Europe and Asia, the whole of northern and tropical Africa, and in Japan. The North American barn-owls, he says, differ only in a few darker tints of the plumage; but the South American ones are distinct.

Tyrannula virens, A. 115. *Mex.* Licht. *Cuba.* 29° N.—50° N.
„ fusca, A. 120. *Mex.* Licht.—57° N.
„ acadica, A. 145. *Mex.* Sw.—50° N.
„ Richardsonii, F.B.A. 46, 2. ?—50°—60° N. (*Labrad.* Aud.)
„ Saya, A. 399. *Mex.* Sw.—54° N. *prairies.*
„ pusilla, A. *app. Mex.* Sw.—56° N.
„ coronata, *enl.* 675, 1. *Mex.* Sw. Licht. *Cal.* Vig. 2° N.—38° N.
„ semi-atra, Vig. *Cal.* 38° N.
„ Traillii, A. 45. ?—36° N. *Arkans.*

Tyrannula Selbii, A. 9. *Louis.* ?—32° N.
„ *cayenensis*, *enl.* 569, 2. 2° N.—*Mex.* Sw. Licht.
„ *affinis*, Sw. *Mex. maritime.*
„ *barbirostris*, Sw. *Mex.*
„ *nigricans*, Sw. *Mex. table l.*
„ *musica*, Sw. *Mex.*
„ *ornata*, Sw. *Mex.*
„ *obscura*, Sw. *Mex.*
„ *despotes*, Licht. *Mex.*
„ *obsoleta*, Licht. *Mex.*
„ *larvata*, Licht. *Mex.*
„ *mesoleuca*, Licht. *Mex.*
„ *atrata*, Licht. *Mex.*
„ *pallida*, Sw. *Mex.*

Fam. MERULIDÆ.

Cinclus americanus, A. 374. *Mex.* Sw.—57° N.
Merula migratoria*, A. 131. *Mex. Cal.*—67° N.
„ aurorea*, Pall. *Kodiak.* 58° N. Temm.
„ Wilsonii, A. 164. 25° N.—57° N.
„ minor*, F.B.A. 36. 25° N.—54° N.
„ mustelina, A. 73. *Mex.* Licht.—50° N.
„ solitaria, F.B.A. 35. 27° N.—50° N.
„ *silens*, F.B.A. *Mex.* Sw. *table l.*
„ *flavirostris*, Sw. *Mex. table l.*
„ *tristis*, Sw. *Mex. table land.*

Orpheus nævius, F.B.A. 38. *Cal. Nootka.* 36° N.—66° N. Vig. Cook.
„ rufus, A. 116. 30° N.—54° N.
„ felivox, A. 128. *Mex.* Licht.—54° N.
„ polyglottus, A. 21. 25° S.—44° N. *Mex.* Sw.
„ leucopterus, Vig. *Cal.* 38° N.
„ *curvirostris*, *col.* 441. Sw. *Mex.*
Turdus * *erythrophthalmus*, Licht. *Mex.*
„ *deflexus*, Licht. *Mex.*
„ *helvolus*, Licht. *Mex.*
Myothera obsoleta, A. 400. *Arkans.* 35° N.
Icteria viridis, A. 137. 23° N.—44° N.

Fam. SYLVIADÆ.

Saxicola œnanthe*, *Behr. Str.* ? Vig. *Greenl.* Sabine. (*œnanthoides.*)
Erythaca sialis, A. 113. *Mex.* Licht. *W. Ind.*—48° N. *Sialia Wilsonii.*
„ arctica, *F.B.A.* 39. *New Cal.* 44° N.—68° N.
„ cœruleo-collis, Vig. *Cal.* 38° N.
„ *mexicana*, Sw. *Mex.*
Anthus aquaticus*, *enl.* 661, 2. *Greenl. N. Am.* Tem.
„ ludovicianus, *F.B.A.* 44. 24° N.—63° N. (*ruber*, Gm.)
„ pipiens, A. 80. *N.W. prairies.*
Motacilla leucoptera, Vig. *Calif.*
Parus bicolor*, A. 39. *Greenl.* Lath. 30° N.—70° N.
„ carolinensis, A. 160. 30° N.—36° N.
„ atricapillus, A. 36° N.—65° N.
„ hudsonicus, A. 194. 44° N.—57° N.

Sylvicola vermivora, A. 34. 23° N.—42° N. (*sub g. Vermivora*, Sw.)
„ solitaria, A. 20. *Mex.*—41° N.
„ chrysoptera, A. 15, 2. 23° N.—50° N.
„ protonotaria, A. 3. 23° N.—38° N.
„ rubricapilla, A. 89. 23° N.—55° N.
„ peregrina, A. 154. 23° N.—55° N.
„ celata, A. 178. 24° N.—50° N.
„ Swainsonii, A. 198. 23° N.—33° N.
„ æstiva, A. 95. *Mex.* Sw. 20° N.—68° N.
„ americana, A. 15. *Mex.* Sw.—46° N.
„ autumnalis, A. 88. 23° N.—48° N.

* *Merula* and *orpheus* of Mr. Swainson correspond with *turdus* of authors; the latter name is retained for Lichtenstein's species, as we do not know to which of the former to refer them.

Sylvicola cœrulea, A. 48. *Mex.*—40° N.
„ carbonata, A. 60. *Kentucky.* 38° N.
„ castanea, A. 69. 24° N.—44° N.
„ discolor, A. 14. 23° N.—43° N.
„ formosa, A. 38. *Mex.*—38° N.
„ icterocephala, A. 59. *Trop.* ?—*Canada* ?.
„ maculosa, A. 50, 123. *Cuba*, VIG.—55° N.
„ pensilis, A. 85. *Cuba.* VIG. *Mex.* SW. LICHT.—36° N.
„ rara, A. 49. ?—43° N.
„ Rathbonia, A. 65. *Mississ.*
„ Childrenii, A. 35. *Louis.*
„ Bachmanii, A. 185. *S. Car.*
„ Blackburniæ, A. 135. *Mex.* SW. *Cuba.*—54° N.
„ palmarum, BON. 10, 2. *W. Ind.* 18° N.—48° N.
„ agilis, A. 138. 23° N.—44° N.
„ canadensis, A. 155. *Cuba.* 20° N.—54° N.
„ coronata, A. 153. *Cuba.* VIG. *Mex.* LICHT. *Cal.* VIG.—20° N.—56° N.
„ parus, A. 134. 23° N.—52° N.
„ petechia, A. 145. 24° N.—55° N.
„ sphagnosa, A. 148. *W. Ind.*—20° N.—46° N.
„ striata, A. 133. *W. Ind.*—54° N.
„ maritima, A. *App.* ?—40° N.
„ virens, A. 393. *Mex.* LICHT.—50° N.
„ tigrina, WILS. 44, 2. ?—45° N.
„ *inornata*, SW. *Mex.*
„ *petasodes*, LICHT. *Mex.*
„ *culicivora*, LICHT. *Mex.*
{ „ varia, A. 90. *Mex.* SW.—50° N.
{ „ pinus, A. 140. 24° N.—50° N.
Setophaga ruticilla, A. 40. 2° N.—62° N. *Mex.* SW.
„ canadensis, A. 103. *Cuba*, VIG.—55° N.
„ Bonapartii, A. 5. 23° N.—34° N.
„ Wilsonii, A. 124. 35° N.—58° N. (*muscicapa pusilla*, WILS.)
Setophaga mitrata, A. 110. 23° N.—52° N. (*cucullata.*)
„ minuta, A. *App.* 23° N.—40° N.
„ *picta*, SW. *Mex. Zool. Ill.*, 2, 54.
„ *miniata*, SW. *Mex. table l.*
„ *rubra*, SW. *Mex. table l.*
„ *rufifrons*, SW. *Mex.*
Trichas marilandica, A. 23, *Mex.* SW. *Cal.* VIG.—50° N. (*personata.*)
„ philadelphia, A. *App.* ?—40° N.
„ Roscoe, A. 24. *Mississ.*
Accentor auricapillus, A. 143. *W. Ind. Mex.* LATH. SW. *table l.*—55° N. (*sub. g. Seiurus*, SW.)
„ aquaticus, WILS. 23, 5. *F.B.A.* 43. *Mex.* SW.—64° N.
Culicivora cœrulea, A. 84. *Mex.* LICHT.—43° N.
Sylvia calendula, A. 195. 24° N.—70° N. *Greenl.* BON. (*sub. g. Regulus.*)
„ Cuvierii, A. 55. 40° N. *prairies.*
„ tricolor, A. 183. 23° N.—54° N.
„ trochilus*, *enl.* 651, 1. *N. Am.* TEMM.

Fam. AMPELIDÆ.

Bombycilla carolinensis, A. 43. *Mex.* LICHT. 2° N.—56° N.
„ garrula*, A. 303. ?—67° N.
Vireo solitarius, A. 23. *Mex.* LICHT.—39° N.
„ noveboracensis, A. 63. *Mex.* LICHT.—45° N.
„ flavifrons, A. 119. 23° N.—46° N.
„ gilvus, A. 118. 23° N.—46° N.
„ olivaceus, A. 150. *Mex.* SW.—55° N. (*musc. altiloqua*, VIEIL.)
„ Bartramii, *F.B.A. Braz. S. Car. New Caled.*—49° N.
„ Vigorsii, A. 30. *Penns.*

Fam. MUSCICAPIDÆ.

Todus viridis, *enl.* 585. *W. Ind. Mex.*
Psaris cayanus, *enl.* 304, 307. 2° N. *Mex.* LICHT.

As the food of the raptorial order of birds, though variable in quantity in different localities, must be almost everywhere very similar in quality, it excites no surprise when we discover that many species are common to different quarters of the world, especially those entering the typical and subtypical groups which prey on quadrupeds and birds, taking them alive. But we are led to expect that the distribution of birds which feed on the fruits of the earth, should be influenced in a greater degree by climate, soil, and consequent fertility of the land :

and as temperature, moisture, and richness of vegetation have a manifest connection with the abundance and variety of insects, we look to find the insectivorous birds of the several continents nearly as different as their floras. Mr. Swainson has indeed already remarked that "it is among the insectivorous or soft-billed birds that the principal ornithological features of any extensive region will be traced." These observations receive a general support by a review of the extensive and varied order of *insessores* which in North America form three fifths of the birds; and though the *hirundinidæ*, which are purely insectivorous, exhibit in the table a large proportion of species common to the two continents, there is, as we shall mention again, reason to doubt the identity of the species in the two faunæ. Two or three species of carnivorous *corvidæ* are with more certainty the same on both sides of the Atlantic, and also several hard-billed granivorous birds (*fringillidæ*) that breed in the arctic regions, the physical conditions of which are almost the same in all longitudes, though below 65° N. latitude the aspect of the two continents differs greatly.

Dentirostres.—In the quinarian arrangement of Mr. Vigors, this is one of the five *tribes* into which the *insessores*, or perchers, are divided, each tribe containing five families. Of the *laniadæ*, a normal family of the tribe, only one species stands in our list as common to the new and old continents, and it is so marked in accordance with the opinions of Wilson and Audubon, but contrary to those of Vieillot, Bonaparte, and Swainson. This and the other North American *lanii* are certainly very similar in form to their European congeners, which may be accounted for by their approaching the *rapaces* in their mode of feeding, and being less exclusively insectivorous than the *tyraninæ*, associated with them by Mr. Swainson, which are proper to America. The *merulidæ*, the other normal family of the tribe, contains three American species which have been enumerated in the European fauna, one (*merula migratoria*) because of its occasional appearance in Germany, and the other two, *m. aurorea* and *minor*, on account of the capture of one or two individuals in Saxony and Silesia. Of the numerous family of *sylviadæ* we scarcely know more than one species which has an undisputed right to be marked as common to both sides of the Atlantic. *Saxicola œnanthe*, hitherto detected only in the higher arctic latitudes of America, may prove on further acquaintance to be distinct from the more southern European bird bearing the same name. Indeed Mr. Vigors has named it *œnanthoides*, being led to consider it to be a proper species, more from its distant habitat than from any peculiar character detected in the speci-

mens from Behring's Straits submitted to him: it was found in Davis's Straits by Captain Sabine. Two species of *anthus* existing in America appear to have been confounded under the name of *aquaticus:* one of them identified by Temminck with the European species; the other, having a much more brown under plumage, is figured in the *Fauna Boreali-Americana* under the name of *aquaticus,* but, as the author last-named has observed, it is in reality a distinct species. It was indeed described as such by Latham under the appellation of the Louisiana lark, and the Prince of Musignano in adopting the specific name of *ludovicianus,* was led to deny the existence of the true *aquaticus* in America. Opinions vary as to the identity of *parus atricapillus* with the *palustris* of Europe. The American and European gold-crests (*reguli*) have also been confounded though they are now held to be distinct. It is to be noticed that the *pari* and *reguli* are typical examples of their respective groups, the *parianæ* or titmice-warblers belonging to America chiefly, while the *sylvianæ* are mostly European warblers. Temminck states that the *sylvia trochilus* belonging to his group of *muscivores* or to *regulus* of Cuvier, exists precisely the same in North America as in Europe, but it has not as yet found a place in the works of the North American ornithologists. *Bombycilla garrula* is the only one of the *ampelidæ* which is common to the two continents, and its manners and the extent of its migrations as well as its form and plumage are absolutely the same on both sides of the Atlantic. The *vireones* which feed on insects, or, when these are scarce, on the berries of the *myrica cerifera,* are confined to the New World. Of the *muscicapidæ* several species belong to the European fauna, but there are no typical ones in America agreeably with Mr. Swainson's views of the constituents of the family: within the tropics and in Mexico we find *psaris cayanus,* a typical black-cap, and *todus viridis,* considered by him to be a fissirostral form of the broad-billed fly-catchers.

Typ. Tribe, Conirostres.

Aber. fam. FRINGILLIDÆ.

Alauda alpestris*, *A.* 200. *Mex.* Sw.—68° N. (*cornuta,* WILS.)
,, *glacialis,* LICHT. *Mex.*
Plectrophanes nivalis*, *A.* 189. 38° N.—75° N. 81° N. *Spitzb.*
,, lapponica*, *A.* 370. 44° N.—70° N. (*calcarata,* TEM.)
,, picta, *F.B.A.* 49. ?—54° N.
Emberiza canadensis, *A.* 188. *Cal.* VIG. 36° N.—60° N.
Emberiza Townsendii, *A.* 369. *Philad.* 40° N.
,, pusilla, *A.* 139. 30° N.—45° N.
,, pallida, *F.B.A.* ?—55° N.
,, socialis, *A.* 104. *Mex.* Sw.—45° N.
,, melodia, *A.* 25. 30° N.—50° N.
,, oonalaschkensis, GM. ?—55° N.
,, *mexicana, enl.* 386. 1. *Mex.*
,, *pusio,* LICHT. *Mex.*

Fringilla palustris, *A.* 64. 30° N.—44° N.
„ iliaca, *A.* 108. 30° N.—68° N.
„ leucophrys, *A.* 114. 28° N.—68° N.
„ grammaca, Bon. 5, 3. *Mex.*—40° N. *prairies.* (*strigata*, Sw.)
„ pennsylvanica, *A.* 8. 23° N.—66° N.
„ graminea, *A.* 94. 30° N.—57° N.
„ hyemalis*, *A.* 13. *Cal.* Vig. 30° N.—57° N.
„ arctica, Vig. *Cal. Unalasch.* 36° N.—55° N.
„ meruloides, Vig. *Cal.* 37° N.
„ crissalis, Vig. *Cal.* 36°, 38° N.
„ amœna, Bon. 6. f. 5. 37° N. *prairies.*
„ cyanea, *A.* 44. *Mex.* ?—45° N.
„ ciris, *A.* 53, 1. 25° S.—36° N.
„ caudacuta, *A.* 149. 33° N.—44° N.
„ maritima, *A.* 93. 30° N.—44° N.
„ *bimaculata*, Sw. *Mex. table l.*
„ *cinerea*, Sw. *Mex.*
„ *epopæa*, Licht. *Mex.*
„ *rhodocampter*, Licht. *Mex.*
„ *superciliaris*, Licht. *Mex.*
„ *lepida*, L. Licht. *W. Ind. Mex.*
„ *hæmorrhöa*, Licht. *Mex.*
„ *melanoxantha*, Licht. *Mex.*

Pipillo erythrophthalma, *A.* 29. 23° N.—48° N.
„ arctica, *F. B. A.* 51, 52. ?—55° N.
„ *maculata*, Sw. *Mex.*
„ *macronyx*, Sw. *Mex.*
„ *fusca*, Sw. *Mex.*
„ *rufescens*, Sw. *Mex.*

Tanagra mexicana, L. *enl.* 290. 2, 155. 1.
„ *ignicapilla*, Licht. *Mex.*
„ *gnatho*, Licht. *Mex.*
„ *grandis*, Licht. *Mex.*
„ *auricollis*, Licht. *Mex.*
„ *erythromelas*, Licht. *Mex.*
„ *abbas*, Licht. *Mex.*
„ *rutila*, Licht. *Mex.*
„ *celæno*, Licht. *Mex.*

Pyranga æstiva, *A.* 44. *Mex.* Licht. 42° N. (*Phœnisoma*, Sw.)
„ rubra, Wils. 11 f. 3, 4. *Mex.* 49° N.
„ ludoviciana, Wils. 20. 1, 2° N.—42° N. *prairies.*
„ *livida*, Sw. *Mex.*
„ *hepatica*, Sw. *Mex.*
„ *bidentata*, Sw. *Mex.*

Euphone jacarina, *enl.* 224. 3, *Braz. Mex.* Licht.

Euphone tibicen, Licht. *Mex.*
„ rufiventris, Licht. *Braz. Cal.* 25° S.—36° N. (*Saltator*, Vig.)

Tiaris pusilla, Sw. *Mex.*

Spermagra erythrocephala, Sw. *Mex.*

Coccothraustes vespertina, *F. B. A.* 68. 45° N.—54° N.
„ ludovicianus, *A.* 127. *Mex.* Sw. 56° N.
„ cœrulea, *A.* 122. *Mex.* Sw. 42° N.
„ cardinalis, *A.* 159. *Mex.* Licht. 23° N.—42° N.
„ ferreo-rostris, Vig. *Cal.* 36° or 38° N.
„ *melanocephala*, Sw. *Mex.*
„ *chrysopelus*, *Zool. pr.* 15. *Mex.* Cuming.

Linaria frontalis, Bon. 6. f. 1. *Mex.* Sw. 38° N. (*Hæmorrhous*, Sw.)
„ purpurea, *A.* 4. 30° N.—55° N.
„ tephrocotis, *F. B. A.* 50. ?—53° N. (*sub. g. Leucosticte.*)
„ borealis*, Vieil. *gal.* 65. Roux, 101. *Greenl. Japan*, Temm. 52° N.—68° N.
„ americana, *A.* 354. ?—44° N.
„ passerina, *A.* 130. 23° N.—45° N.
„ Bachmanii, *A.* 165. ?—35° N.
„ Henslowii, *A.* 70. 30° N.—37°. N.
„ savanna, *A.* 109. 30° N.—52° N.
„ Lincolnii, *A.* 193. ? 40° N.—52° N.

Carduelis tristis, *A.* 23. *Mex.*—60° N.
„ pinus, *A.* 180. 32° N.—52° N.
„ psaltria, Bon. 6. f. 3. *Mex.* ?—*R. Platte.*
„ mexicana, Sw. *Mex. U. St.* Aud.
„ *catotl*, Gmel. *Mex.*

Pyrrhula enucleator*, *A.* 358. 50° N.—63° N. (*Corythus*, Cuv.)
„ inornata, Vig. *Cal.* 38° N.

Loxia curvirostra*, *A.* 197. 40° N.—57° N.
„ leucoptera*, *A.* 368. 40° N.—68° N.

Typ. fam. Corvidæ.

Corvus corax*, *A.* 101. *Cal.* Vig. 26° N.—74° N.
„ corone*, *A.* 156. 26° N.—55° N.
„ ossifragus, *A.* 146. 24° N.—40° N.
„ columbianus, *A.* 397. 46° N. *Pacific.*
„ *mexicanus*, *L. Mex.* Licht.
„ *morio*, Licht. *Mex.*

Pica caudata*, *A.* 358. 40° N.—58° N. *prairies.* (*Corvus pica.*)
„ *peruviana, enl.* 625. *Mex.* LICHT.
„ *Beechei,* VIG. *Mex. Montereale.*
„ *Colliei,* VIG. *Mex. San Blas.*
Garrulus Bullockii, *A.* 96. *Mex. Cal.* BON. 46° N. (*gubernatrix, col.* 436.)
„ floridanus, *A.* 87. 25° N.—31° N. (*Cyanurus,* Sw.)
„ Stelleri, *F.B.A.* 54. *Mex.* BON. —57° N.
„ cristatus, *A.* 102. 25° N.—56° N.
„ californicus, VIG. *Monterey.* 36° N.
„ *coronatus,* Sw. *Mex.*
„ *azureus, col.* 108. *Mex.* LICHT.
„ *formosus,* Sw. *col.* 436. *Mex. Temiscalt.*
„ canadensis, *A.* 107. 42° N.—68° N. (*Dysornithia.*)

Sub-typ. fam. STURNIDÆ.

Molothrus pecoris, *A.* 99. *Mex.* Sw. 56° N.
Dolichonyx agripennis, *A.* 54. *Mex.* Sw. —54° N. (*oryzivora,* Sw.)
Agelaius phœniceus, *A.* 67. *Mex.* Sw. *Cal.* VIG.—56° N.
Agelaius xanthocephalus, *A.* 396. *Mex.* —58° N.
„ *mexicanus,* EDW. 243. *Mex.*
„ *longipes,* Sw. *Mex. table l.*
„ *Bullockii,* Sw. *Mex.*
Sturnella ludoviciana, *A.* 136. *Mex.* Sw. LICHT. *Cal.* VIG.—56° N.
„ *holosericea,* LICHT. *Mex.*
Xanthornus baltimore, *A.* 12. *Mex.* Sw. LICHT.—55° N.
Icterus spurius, *A.* 42. 2° N.—49° N.
„ *mexicanus,* LEACH, *Zool. Misc.* 2. *Mex.* Sw.
„ *dominicensis, enl.* 5. 1. *W. Ind. Mex.* Sw.
„ *cucullatus,* Sw. *Mex.*
„ *melanocephalus,* Sw. *Mex.*
„ *crassirostris,* Sw. *Mex.*
„ *gularis,* LICHT. *Mex.*
„ *calandra,* LICHT. *Mex.*
Cassicus coronatus, Sw. *Mex.*
Quiscalus versicolor, *A.* 7. *W. Ind.* 57° N.
„ major, *A.* 187. *W. Ind. Mex.* 35° N.
„ *dives,* LICHT. *Mex.*
„ *palustris,* Sw. *Mex.*
Scolecophagus ferrugineus, *A.* 157. 24° N. —68° N.
„ *mexicanus,* Sw.

Conirostres.—Most of the North American species of this, which is the typical tribe of insessorial birds, belong to the *fringillidæ,* one of the aberrant families. The two normal families also include a tolerable number of species, but the two remaining aberrant families (*musophagidæ* and *buceridæ*) have no members in North America. Among the *fringillidæ* we find one *alauda,* two *plectrophanes,* one *fringilla,* two *linariæ,* one *pyrrhula,* and two *loxiæ,* common to the two countries. In addition to these the *alauda calandra* of the south of Europe is noted in the *Fauna Boreali-Americana* as having been taken at Hudson's Bay, but as the only authority is a specimen in the British Museum of not very certain origin, it is omitted in the preceding list. The perfection of ornithological structure is to be found, according to Mr. Swainson, in the *corvidæ,* the typical family of the *conirostres,* or typical tribe of the insessorial or typical order. The raven, which is a typical example of the genus *corvus,* is common to the four quarters of the world, and most ornithologists consider the carrion crow and the magpie of America to be the same with those of Europe. Mr. Audubon, however, describes the former as a peculiar species under the name of *americanus,* and Mr. Sabine has treated the magpie in a similar manner, though he has not been followed by subsequent writers:—it is certain that he has failed in pointing out any constant or appreciable

differences of plumage, but there is something peculiar in the habits of the American bird which frequents the interior prairie lands, and does not approach the sea coast as in Europe, nor does it go to the north of the 58th parallel, though the European bird extends to Lapland. Further observations are required to prove that the differences in the form and size of the eggs noted in the *Fauna boreali-americana* are constant. The common magpie abounds in Japan, as Temminck informs us. The *sturnidæ* are more numerous in America than in Europe, and are all proper to the country.

Aber. tribe, Scansores.

Typ. fam. PICIDÆ.

Picus principalis, *A.* 66. 25° N.—37°N.
„ tridactylus*, *A.* 132. 40° N.—68° N. (*americanus, arcticus*).
„ pubescens, *A.* 112. 30°N.—58°N.
„ villosus, *A.* 360. *Cal.* VIG. 28° N. 63° N.
„ querulus, *A.* 353. 30° N.—36°N.
„ carolinus, *A.* 391. 19° N.—46°N.
„ varius, *A.* 190. *Mex.* SW.—61° N.
„ formicivorus, *Col.* 451. *Mex.* LICHT. SW. *Calif.* VIG. 36°N.
„ *scapularis*, VIG. *Mex. San Blas.*
„ ? *olegineus*, LICHT. *Mex.*
„ ? *poliocephalus*, LICHT. *Mex.*
„ canus*, EDW. 65. *N. Am.* TEMM.
„ pileatus, *A.* 111. *Mex.* 63° N.
Colaptes auratus, *A.* 37. 25° N.—63° N.
„ mexicanus, VIG. 9. *Mex. Cal.* —49° N. (*collaris*, VIG.)
Melanerpes torquatus, *A.* 395. 30° N.—40° N.
„ erythrocephalus, *A.* 27. 24° N. —50° N.
„ ruber, *Cal.* VIG. *Nootka.* COOK. 2° N.—50° N.
„ ? *aurifrons*, LICHT. *Mex.*
„ *albifrons*, SW. *Mex. Table L.*
„ *elegans*, SW. *Mex. marit.*

Sub-typ. fam. PSITTACIDÆ.

Psittacus melanocephalus, *enl.* 527. 2° N. —*Mex.*
„ *leucorhynchus*, SW. *Mex.*
„ *autumnalis*, EDW. 164. 2° N. —*Mex.* LICHT.
„ *strenuus*, LICHT. *Mex.*
Plyctolophus mexicanus, GMEL., LICHT.
Macrocercus militaris, VAILL. 4. *Mex. Table L.* SW. *San Blas.* VIG.
„ *pachyrhynchus*, SW. *Mex.*
Macrocercus aracanga, *enl.* 2. 2° N.—*Mex.* LICHT.
Psittacara carolinensis, *A.* 26. *Mex.* LICHT. —42° N.
„ *guianensis*, SPIX. 25. 2° N.—*Mex.* LICHT. (*Agapornis*, SW.)
„ *pertinax*, *enl.* 528. 25° S. *Mex.* LICHT.
Psittacula mexicana, GMEL., LICHT.

Aber. fam. RAMPHASTIDÆ.

Pteroglossus pavoninus, *Zool. Pr.* 34. *Mex.*
Ramphastos pœcilorhynchus, LICHT. *Mex.*

Aber. fam. CUCULIDÆ.

Coccyzus americanus*, *A.* 2. ?—45° N.
„ erythrophthalmus, *A.* 32. ?—45° N.
„ seniculus, *A.* 169. 2° N.—25° N.
„ *mexicanus*, SW. *Table L.*
„ *cayanus*, *enl.* 211. 2° N.—*Mex.* LICHT.
„ *viaticus*, LICHT. *Mex.*
Crotophaga ani, *enl.* 182, 1, 2. 2° N.—*Mex.* LICHT.
„ *sulcirostris*, SW. *Mex. Table L.*
Leptostoma longicauda, SW. *Mex.* (*Saurothera californica*, LESS. ?)

Aber. fam. CERTHIADÆ.

Troglodytes hyemalis, *A.* 365. 40° N.—46° N. (*Sylv. troglodytes*).
„ furvus, *A.* 83. *Surin.* BON. 5° N. —57°N. (*domestica, aëdon*).
„ americanus, A. 179. 32° N.—46° N.
„ spilurus, VIG. 4. *Calif.* ? or *Mex.* ?
„ palustris, *A.* 100. 25° N.—55° N. (*Thryothorus*).

Troglodytes Bewickii, *A.* 18. *Louis.*
„ ludovicianus, *A.* 78. 30° N. 42° N. (*carolinianus*).
„ brevirostris, *A.* 175. 26° N.—44° N.
„ *murarius*, LICHT. *Mex.*
„ *mexicanus*, LICHT. *Mex.*
„ *latifasciatus*, LICHT. *Mex.*
Certhia familiaris*, *A.* 392. 30° N.—50° N.
Sitta carolinensis, *A.* 152. *Mex.* Sw.—46° N.
„ canadensis, *A.* 105. 38° N.—52° N.
„ pusilla, *A.* 125. 24° N.—40° N.
„ pygmæa, VIG. 4, 2. *Calif. Monterey.* 36° N.
Xiphorynchus leucogaster, Sw. *Mex.*
„ *flavigaster*, Sw. *Mex.*
Dendrocolaptes pœcilinotus, WAGL. *Mex.* LICHT.

We may remark of the scansorial birds in general that they are very numerous on the American continent, and particularly in the intertropical and southern regions, where they find abundant food in the ancient and interminable forests which they inhabit. The North American fauna contains examples of all the five families, the typical group being, however, most plentifully and generally distributed in the middle districts. Three species only of the whole tribe are common to the European and American faunæ, viz. *picus tridactylus**, which is the most northern scansorial bird, and *canus* (*malacolophus*) Sw., which is introduced into our list on the authority of Temminck, who says that it inhabits the north of Europe, Asia, and America: both these belong to the typical family. The third species is *certhia familiaris*, a type of one of the aberrant families. Doubts existed as to the difference between *troglodytes europæus* and *hyemalis*, but they have been abandoned by the latest writers. The European fauna contains no example of the *psittacidæ* or *ramphastidæ*, and in America the *psittacara carolinensis* alone passes the parallel of the south of Europe: a species of parrot reaches the thirty-second degree of latitude in the north of Africa. The *coccyzus americanus* has been recently added to the list of European birds, four individuals having been killed in Great Britain, consequently it attains a higher latitude there by five or six degrees than it does on the other side of the Atlantic. Temminck objecting to the geographical designations of *americanus*, *carolinensis* and *dominicus*, in which this species rejoices, has named it *cinerosus*, being a translation of Buffon's epithet *cendrillard*.

Aber. tribe, Tenuirostres.

Typ. f m. TROCHILIDÆ.

Trochilus rufus, JARD. 6. *Real del Monte*, Sw. 61° N. (*collaris*, LATH.)
„ *montanus*, LESS. 33, 54. *Mex.*
„ *platycircus*, Sw. *Mex.*
„ Anna, LESS. 74. *Cal.* 30° N.—57° N.
Trochilus *Rivolii*, LESS. 4. *Mex.*
„ *melanotus*, Sw. *Mex.*
„ *fulgens*, Sw. *Mex.*
„ *latirostris*, Sw. *Mex.*
„ *bifurcatus*, Sw. *Mex.*
„ *minimus*, Sw. *Mex.*

* Mr. Swainson says the European and American three-toed woodpeckers are distinct species.

Trochilus *tricolor*, Sw. *Mex.*
„ *beryllinus*, Licht. *Mex.*
„ *verticalis*, Licht. *Mex.*
„ *cuculiger*, Licht. *Mex.*
„ *curvipennis*, Licht. *Mex.*
„ *hemileucurus*, Licht. *Mex.*
„ *coruscus*, Licht. *Mex.*
Cynanthus colubris, *A.* 47. *W. Ind.* 57° N.
„ *lucifer*, Less. 5. *Mex.* Sw.
„ *tricolor*, Less. 14. *Mex.*
„ *Dupontii*, Less. *sup.* 1. *Mex.*
„ *thalassinus*, Less. 55, 56, 57. *sup.* 3. *Mex.*
Cynanthus *arsinoe*, Less. *sup.* 28. *Mex.*
Campylopterus Clementiæ, Less. 30. *Mex.*
Lampornis mango, *A.* 184. 25° S.—25° N. *Braz. Mex. Flor.*
„ *gramineus*, Less. *col.* 12. *Mex.*
„ *cœligena*, Less. *tr.* 53. *Mex.*
„ *melanogaster*, Vieill. 75. *Mex.*
„ *punctatus*, Vieill. 8. *Mex.*
„ *holosericeus*, Edw. *W. Ind. Mex.* 4° N.—20° N.
„ *gutturalis*, *enl.* 671. 4° N. *Mex.*

The tenuirostral tribe, containing the five families of *trochilidæ, cinnyridæ, meliphagidæ, paradisidæ,* and *promeropidæ,* is represented in Europe only by the hoopöe, one of the *promeropidæ,* while many *trochilidæ* belong to the North American fauna, of which, however, but three range northwards to European parallels. The alpine structure of Mexico, by producing a succession of various climates within a short space, adapts it admirably to the habitation of the *trochilidæ* which seek their food in the throats of flowers. Mr. Swainson observes, that the vast proportion of suctorial birds inhabiting Australia and the neighbouring groups of islands, is one of the characteristics of that zoological province, the honey-sucking birds forming nearly one-fourth of the New Holland perchers,—for that character belongs not only to the *meliphagidæ,* but also to the little green lories (*trichoglossi*) of the parrot family. The *paradisidæ* are natives of New Guinea which is a portion of the Australian province. The greater prevalence of this form in South America and Australia affords another instance of analogy between their faunæ, in addition to those noticed in our remarks on the mammalia. The *cinnyridæ* and *promeropidæ* inhabit the warmer regions of the old world.

Aber. tribe, Fissirostres.

Aber. Fam. Halcyonidæ.

Alcedo alcyon, *A.* 77. *W. Ind.*—68° N.

Typ. Fam. Hirundinidæ.

Hirundo purpurea, *A.* 22. *Braz.* Sw. 9° S. —67° N.
„ rustica*, *A.* 173. *Mex.* Licht.—68° N. (*rufa, americana*).
„ riparia*, *A.* 389. 25° S.—68° N.
„ bicolor, *A.* 98. *Mex.* Licht.—60° N. (*viridis*).
„ fulva, *A.* 68. *W. Ind.* Vieill. *Mex.* Sw.—67° N. (*lunifrons?*)
„ aoonalaschkensis, Lath., ?—60° N.
Hirundo thalassina, Sw. *Mex.*
„ *coronata*, Licht. *Mex.*
Chætura pelasgia, *A.* 158. ?—25° N.—50° N.

Sub. typ. fam. Caprimulgidæ.

Caprimulgus vociferus, *A.* 82. ?—25° N. —48° N.
„ carolinensis, *A.* 52. *Mex.*—37° N.
„ virginianus, *A.* 147. ?—25° N.—68° N. (*Chordeiles*, Sw.)
„ *albicollis*, Lath. 4° N.—*Mex.* Licht.

Aber. fam. TROGONIDÆ.

Trogon viridis, enl. 195. 2° N.—*Mex.* LICHT.
„ *glocitans,* LICHT. *Mex.*
„ *pavoninus, col.* 372. *Mex.*
Trogon mexicanus, SW. *Temiscalt.*
„ *resplendens, Zool. pr.* 27. *Mex.*
„ *elegans, Zool. pr. Mex.*
„ *ambiguus, Zool. pr. Mex. Nath. pr.*
„ *Morganii,* SW. *Mex.*
Prionites mexicanus, SW. *Mex. Table L.*

The *meropidæ,* one of the aberrant families of the fissirostral tribe, have no members in America, though two species enter Europe, the rest of the group being confined to the warmer regions of the old continent. The *trogonidæ* again, another aberrant family peculiar to America, though pretty numerous in Mexico, send no species so far north as to reach the United States.* The third aberrant family, the *halcyonidæ,* contains one European species and one North American one. The two normal families are spread over the whole world, and are represented in Europe and North America by nearly an equal number of species, though few are really common to the two countries. The chimney or barn swallow of America is considered by Audubon as the same with that of Europe; though previous authors, relying upon some differences in the colour of the plumage, had named it, as a distinct species, *rufa* or *americana.* The sand-martin (*riparia*) has been described as the same in both continents without much question, but also perhaps without a correct comparison of a sufficient number of specimens from both continents. The interesting species named *fulva* requires further investigation; by Vieillot, who gave it that appellation, it is said to have a forked tail, which form is also attributed to it in the *Fauna boreali-americana,* where Say's appellation of *lunifrons* is adopted: Audubon and the Prince of Musignano, who inspected Say's specimen, describe the tail as square. It remains to be ascertained whether these authors all speak of the same species or not.

Aber. Ord. RASORES.

Aber. fam. CRACIDÆ.

Crax hoazin, ALBIN 32. *Mex.*
Ourax pauxi, enl. 78. 2° N.—*Mex.*
Penelope garrula, WAGLER, *Mex.* LICHT.

Aber. fam. COLUMBIDÆ.

Columba fasciata, BON. 8, 3. *R. Platte.*
„ leucocephala, *A.* 177. *W. Ind. Mex. Floridas.*—25° N.
„ monilis, VIG. 10. *Cal.* 36° N.
Ectopistes migratoria*, *A.* 62. 25° N.—62° N. *Greenl. accid.*
„ carolinensis, *A.* 17. *Mex.* LICHT.—42° N. *L. Super.*
Peristera montana, *A.* 167. 2° N.—25° N.
„ zenaida, *A.* 162. *Cuba.*—25° N.
Peristera jamaicensis, TEM. 10. *Mex.* LICHT.
„ *pusilla,* LICHT. *Mex.*
Geophilus cyanocephalus, *A.* 172. *W. Ind.*—25° N. *Florida.*
Chamœpelia passerina, *A.* 182. *W. Ind.*—32° N. *Cape Hatteras.*
„ *squamosa,* TEM. 59. 25° S.—*Mex.* LICHT.

PHASIANIDÆ *or* PAVONIDÆ.

Meleagris gallopavo, *A.* 1. *Mex.*—44° N.

TETRAONIDÆ.

Tetrao { umbellus, *A.* 41. 32° N.—56° N.
„ { cupido, *A.* 186. 36° N.—46° N.

* Mr. Swainson has recently indicated a *prionites bahamensis.*

Tetrao canadensis, *A.* 176. 44° N.—68° N. *Moist Woods.*
" Franklinii, *F.B.A.* 61. 50° N.—58° N. *Rocky Mount.*
" obscurus, *A.* 361. 40° N.—63° N.
" mutus*, LEACH. 67° N.—70° N.
" rupestris*, *A.* 373. 55° N.—75° N. *Barren Grounds.*
" leucurus, *F.B.A.* 63. 54° N.—64° N. *Rocky Mount.*
" saliceti*, ED. 72. 45° N.—70° N.
Tetrao urophasianus, *A.* 366. 42° N.—48° N. *Prairies of the Columb.*
" phasianellus, *A.* 367. 36° N.—61° N.
Ortyx virginiana, *A.* 76. *Mex.*—48° N.
" californica, SHAW. *Mis.* 345. 36° N.—44° N.
" Douglasii, VIG. 9. *Cal.* 36° N.—42° N.
" picta, DOUG. 38° N.—45° N.
" *spilogaster, Zool. pr.* 15. *Mex.* CUM.
" *cristata, enl.* 126. *f.* 2° N.—*Mex.*

The families of *rasores* are capable of being distributed pretty correctly into geographical groups. Thus the *cracidæ* belong to South America, a few species extending northwards to Mexico: one genus (*megapodius*) inhabiting New Guinea, forms another link of connection between the Australian and South American faunæ. The *struthionidæ* belong mostly to the warmer parts of the old continent, one form (the New Holland *emeu*) inhabiting Australia, and another (*rhea*) South America. The *phasianidæ* also have their head quarters in the more southern parts of the old world, one genus only (*meleagris*), composed of two species, being American. The *columbidæ*, on the other hand, are spread generally over the world, though the family contains several well-marked minor geographical groups. The *tetraonidæ* are likewise widely diffused, but chiefly in the colder or temperate regions; and it is to this family that the only rasorial birds common to both continents belong,—they are ptarmigans, inhabiting the most northern districts, (*tetrao mutus, rupestris* and *saliceti*). On comparing this division of the faunæ of North America and Europe with each other we find that the former wants the partridges so common in the temperate parts of the latter, the true pheasants, the genus *otis*, and the *pterocles* and *hemipodii* which have spread to the south of Europe from Africa and Asia; on the other hand it possesses several forms of *columbidæ*, not known in Europe; the magnificent turkey, which for culinary purposes ranks as the chief not only of the *gallinacei* but of the whole feathered race; several singular forms of *tetrao*; and the beautiful californian quails (*ortyx*); besides the Mexican *cracidæ*, which, as they do not go so far north as the southern extremity of Europe, do not fairly come into the comparison. In short, the similarity of this portion of the two *faunæ* is confined to one group of *columbæ*, which does not reach higher than the southern parts of the United States, to the arctic *lagopi*, and to another group of *tetraones*, which includes *canadensis*, but is not generically distinct from the typical grouse.

Aber. Ord. GRALLATORES.

Aber. fam. TANTALIDÆ.

Tantalus loculator, A. 216. 25° S.—38° N. ORD.
Ibis rubra, A. 385. 25° S.—36° N.
„ alba, A. 222. *Mex.* 25° S.—40° N.
„ falcinella*, A. 386. *Mex.*—46° N.
Cancroma cochlearia, enl. 38 & 369. 30° S.—*Mex.* LICHT.
Aramus scolopaccus, A. 381. 2° N.—*U. S.* BON.

Sub-typ. fam. ARDEIDÆ.

Grus americana, A. 226. *Mex.*—68° N.
Ardea herodias, A. 211. 25° N.—50° N.
„ ludoviciana, A. 217. 24° N.—36° N. *Charlestown.*
„ occidentalis, A. 281. *Flor. keys.* 26° N.
„ { candidissima, A. 242. 24° N.—42° N. *Massachusetts.*
„ rufescens, A. 256. *Flor. keys.* 26° N. (*Pealii.*)
„ egretta*, A. 378. *W. Ind. Mex.* 2° N.—43° N. (*alba*). }
„ { cœrulea, A. 307. *Mex. W. Ind.* 2° N.—44° N.
„ virescens, A. 333. *Mex. W. Ind.* —44° N.
„ lentiginosa, A. 337. 38° N.—58° N. (*minor*). }
„ exilis*, A. 210. *W. Ind. Cal.* VIG. 45° N.
„ { nycticorax*, A. 236. *Mex.*—46° N.
„ violacea, A. 336. *Mex. W. Ind.*—2° N.—44° N. }
Platalea ayaia, A. 321. *Mex.* LICHT. 25° S.—40° N.
Hæmatopus palliatus, A. 223. *Mex.* LICHT. 54° S. KING.—52° N.
„ ostralegus*, WILS. 64, 2. *Cal.* VIG.—50° N.

Typ. fam. SCOLOPACIDÆ.

Numenius longirostris, A. 231. *Mex.* LICHT. *Cal.* VIG.—42° N.
„ borealis, A. 208. *Cal.* VIG. 25° S.—70° N. *Labrad. Coperm. r.*
„ hudsonicus, A. 237. ?—60° N.
„ rufiventris, VIG. *Cal.* 36° N.
Totanus glottis*, A. 269. *W. Ind. Flor. keys.*—25° N.
„ flavipes, A. 288. *Mex.* LICHT. *Cuba.*—68° N.
Totanus melanoleucus, A. 308. *W. Ind.*—60° N. (*vociferus*, WILS.)
„ macularius*, WILS. 59. *Mex.* LICHT.—57° N.
„ Bartramius*, A. 303. ?—55° N.
„ { chloropygius, WILS. 58. *Mex.* LICHT. *Cuba.*—68° N.
„ ochropus*, *F.B.A.* ?—58° N. }
„ calidris*, *F.B.A.* ?—58° N.
„ fuscus*, *enl.* 875. *N. Am.* TEMM.
„ { semipalmatus*, A. 274. 23° N.—56° N.
„ candidus, EDW. 139. ?—58° N. }
Recurvirostra americana, A. 318. *Tropics*—63° N.
„ occidentalis, VIG. 12. *Cal.* 38° N.
Limosa fedoa, A. 238. 21° N.—68° N.
„ { hudsonica, A. 258. 38° N.—68° N.
„ melanura*, *enl.* 874. *U. S.* BON. *an preced.* ? }
„ candida, EDW. 139. *enl.* 873. *H. Bay.*
Scolopax minor, A. 268. 26° N.—52° N.
„ Wilsonii*, A. 243. 28° N.—55° N.
„ leucura, *F.B.A. Huds. B.* 57° N.
„ grisea*, A. 335. 50° N.—70° N.
Phalaropus fulicarius*, A. 255. ?—75° N.
„ glacialis, LATH. *Behr. St.* 69½° N.
Lobipes hyperboreus*, A. 215. ?—75° N.
„ Wilsonii, A. 254. *Mex.* SW. *S. Am.*—55° N. (*fimbriatus*, TEM.)
Tringa islandica*, A. 315. ?—75° N.
„ maritima*, A. 284. 40° N.—74° N.
„ Temminckii*, *col.* 41, 1. *Cal.* VIG. *U. S.* BON.
„ minuta*, NAUM, 21, 30. *U. S.* BON.
„ pusilla, A. 320. *Mex.* LICHT. *Nootka.*—68° N.
„ maculosa, VIEILL. *W. Ind.*—*U. S.*
„ { rufescens*, A. 265. 30° N.—70° N.
„ subarcuata*, A. 263. ?—39° N. & 41° N.—? (*africana*, LATH.) }
„ pygmæa*, NAUM. 10, 22. *U. S.* BON. (*platyrhinca.*)
„ { pectoralis*, A. 294. *W. Ind.* 19° N.—?
„ Schinzii*, A. 278. 25° N.—55° N.
„ alpina*, WILS. 56, 2. 57, 3. ?—74° N. (*cinclus, variabilis.*) }
„ { himantopus, A. 344. ?—60° N.
„ semipalmata*, A. 350. ?—60° N. }
„ *Deppii*, LICHT. *Mex.*
Calidris arenaria*, WILS. 59, 4. 63, 3. 30° N.—60° N.

Aber. fam. RALLIDÆ.

Parra jacana, enl. 322. 25° S.—*Mex.*
Rallus virginianus, A. 205. 24° N.—50° N.
„ crepitans, A. 204. 24° N.—41° N.
„ elegans, A. 203. 24° N.—40° N.
Crex noveboracensis, A. 329. ?—57° N.
„ carolinus, A. 233. *Mex.* 25° S.—62° N.
Gallinula chloropus*, A. 244. *Mex. Cal.*—40° N. (*galeata*, BON.)
„ martinica, A. 305. 18° N.—35° N.
Fulica americana, A. 239. *Mex.* LICHT. *Cal.* VIG.—56° N. (*atra*).

Aber. fam. CHARADRIADÆ.

Strepsilas interpres*, A. 304. 24° N.—75° N.
Strepsilas melanocephalus, VIG. *Calif.* ?
Charadrius pluvialis*, A. 300. 23° N.—75° N. *Behr. St.*
„ vociferus, A. 225. *W. Ind.*—56° N.
„ Wilsonius, A. 209. 24° N.—44° N.
„ melodus, A. 220. *Cal.* 24° N.—53° N. (*hiaticula*, WILS.)
„ semipalmatus, A. 330. *Cal.* 24° N. 70° N.
Vanellus melanogaster*, A. 334. 26° N.—70° N. (*helveticus*).
„ *Cayenensis, enl.* 836. *Mex.* ? VIG.
Himantopus nigricollis, A. 328. ?—44° N.
„ *melanopterus**, *enl.* 878. 25° S.—*Mex.* LICHT. *Brazil, Egypt*, TEM.

The principal forms of the *grallatorial order* are the same in the northern divisions of the two continents; but there are five minor genera, viz., *ciconia, glareola, porphyrio,* and *cursorius* in Europe, which do not occur in North America; and three in the latter country, namely, *aramus, tantalus,* and *parra,* which do not belong to the fauna of Europe. The forms and very many of the species of the typical family (the *scolopacidæ*) are absolutely the same in both countries, and on referring to the table in page 167, it will be seen how nearly the number of species of most of the families correspond on both sides of the Atlantic; the numbers would agree still more exactly in the principal group but for recent refinements in the discrimination of species, by which birds, so closely resembling the common snipe as not to be distinguishable by an ordinary observer, are described as distinct on account of some differences in the tail-feathers. The American coot differs very slightly from the European one, and the constancy of these differences still requires to be established; the latter occurs in India without change of form. The Rev. Mr. Bachman and Mr. Audubon have clearly established the brown crane, *grus canadensis,* to be the young of the great hooping-crane, *grus americana.*

Aber. Ord. NATATORES.

ANATIDÆ.

Phœnicopterus ruber*, WILS. 66, 4. ?—40° N. BON.
Anas clypeata*, A. 327. *Mex.* SW. LICHT. *Cal.* VIG.—70° N.
„ strepera*, A. 348. *Mex.* SW. 68° N.
„ acuta*, A. 227. *Mex.* SW. *Cal.* VIG.—70° N.
„ urophasianus, VIG. 14. *Cal.* ?
„ boschas*, A. 221. *Mex.* LICHT. —68° N.
Anas obscura, A. 302. 25° N.—45° N.
„ discors, A. 313. *Mex.* LICHT. *Cal.* —58° N.
„ crecca*, A. 228. *Cal.* VIG. 24° N. —70° N.
„ glocitans*, A. 338.
„ americana, A. 345. *Cuba. Cal.* VIG.—68° N. (*Mareca*).
„ sponsa, A. 206. *Mex. Cal.* VIG. 19° S.—54° N.
Somateria mollissima*, A. 246. 39° N.—81° N. *Greenl. Spitzb.*

Somateria spectabilis*, A. 276. 43° N.—81° N. *Greenl. Spitzb.*
Oidemia perspicillata*, A. 317. *Nootka.* 24° N.—72° N.
„ fusca*, Wils. 72. f. 3. 36° N.—72° N.
„ nigra*, Wils. 72. 2. 36° N. ? N.
„ americana, A. 349. *U. S.*—62° N.
Fuligula valisneria, A. 301. *Cal.* 38° N.—68° N.
„ ferina*, A. 322. *Cal.* 38° N.—68° N.
„ marila*, Wils. 69. 5. 38° N.—68° N. *Cal.* Vig.
„ labradora, A. 332. 40° N.—58° N.
„ rufitorques, A. 234. 26° N.—68° N. (*fuligula*, Wils.)
„ rubida, A. 343. 26° N.—58° N.
Clangula vulgaris*, A. 342. 26° N.—68° N. (*clangula*, Auct.)
„ Barrovii, *F.B.A.* A. 70. ?—57° N.
„ albeola, A. 325. *Mex. Cal.* Vig. —68° N. (*bucephala*).
„ histrionica*, A. 297. *Cal.* Vig.—74° N.
Harelda glacialis*, A. 312. 36° N.—75° N.
Mergus cucullatus*, A. 232. 24° N.—68° N.
„ merganser*, A. 331. 38° N.—68° N.
„ serrator*, A. 382. 38° N.—68° N.
„ albellus*, A. 347. 38° N.—? N.
Cygnus buccinator, A. 377. 38° N.—68° N.
„ Bewickii*, A. 387. *Cal.*—75° N.
Anser canadensis, A. 201. 26° N.—70° N.
„ Hutchinsii, A. 277. 45° N.—69° N. *Melville peninsula.*
„ bernicla*, A. 380. 26° N.—73° N.
„ leucopsis*, A. 296. ?—? *U. S.* Bon.
„ segetum*, *enl.* 985. *U. S.* Bon.
„ hyperborea*, A. 376. 26° N.—73° N.

Colymbidæ.

Podiceps carolinensis, A. 248. 26° N.—68° N.
„ cornutus*, A. 259. 26° N.—68° N.
„ cristatus*, A. 292. *Mex.*—68° N.
„ rubricollis*, A. 298. 41° N.—68° N.
Podoa surinamensis, *enl.* 893. 2° N.—40° N. Bon.
Colymbus glacialis*, A. 306. 26° N.—70° N.
„ septentrionalis*, A. 202. 36° N. —74° N.
„ arcticus*, A. 346. ?—70° N.

Alcadæ.

Uria Brunnichii*, A. 245. 42° N.—75° N.
Uria grylle*, A. 219. 37° N.—75° N.
„ troile*, A. 218. 41° N.—61° N.
„ marmorata, Lath. *N.W. coast.* Bon.
„ alle*, A. 339. 39° N.—75° N.
„ brevirostris, Vig. *Kotzebue Sound.*
Mergulus cirrhocephalus, Vig. *Kotzebue Sound.*
Fratercula glacialis, A. 293. *U. S.* Bon. *Kotzebue Sound.* Vig. 70° N.
„ cirrhata, A. 249. 40° S.—70° N. *Kotzebue Sound.* Vig.
„ arctica*, A. 213. 32° N.—? N.
Phaleris cristatella, *col.* 200. 50° N.—70° N. *Aleut. isles ?* Vig.
„ psittacula, *Pall. sp.* v. 2. *Sea of Kamtsch.*
Alca torda*, A. 214. 40° N.—57° N.
„ impennis*, A. 341. ?—75° N.
Cerrorhincha occidentalis, Bon. *Behr. St.* Vig.

Pelecanidæ.

Onocrotalus americanus, A. 311. *Mex.* Vig.—61° N.
Pelecanus thajus, S. 40°.—*Mex.* Licht.
Phalacrocorax carbo*, A. 266. 40° N.—53° N.
„ dilophus, A. 257. 33° N.—55° N.
„ floridanus, A. 252. 24° N.—35° N.
„ graculus*, *enl.* 974. 40° N. Bon.
„ cristatus*, *col.* 322. 40° N. Bon.
„ pygmæus*, Pall. *Voy.* 1. *U. S.* Bon.
„ *brasilianus*, Spix. 106. 25° S.—*Mex.* Licht.
Sula fusca, A. 251. *Mex.* Vig. 2° N.—35° N. *Flor. S. Carol.*
„ bassana*, A. 326. 40° N. Bon.
Tachypetes aquilus, A. 271. *Mex.* Vig. 23° S.—40° N. Bon.
Phaeton æthereus, A. 262. 30° S. Less. —25° N. Aud.
Plotus anhinga, Wils. 74. 1 & 2. 25° S. —36° N. (*melanogaster*).

Laridæ.

Sterna hirundo*, A. 309. 38° N.—57° N. (*Wilsonii*, Bon.)
„ arctica*, A. 250. 38° N.—75° N.
„ cantiaca*, A. 279. 24° N.—33° N.
„ Dougalli*, A. 240. ?—26° N.
„ cayana, A. 273. 23° N.—54° N.
„ fuliginosa, A. 235. 49° S.—40° N.
„ nigra*, A. 280. *Mex.*—69° N.
„ aranea*, A. 383. 36° N.—44° N.
„ minuta*, A. 319. ?—44° N.
„ stolida, A. 275. 25° S.—24° N.
„ *galericulata*, *Mex.* Licht.

Larus glaucus*, A. 379. ? N.—75° N.
„ argentatus*, A. 291. 24°N.—75°N.
„ leucopterus*, A. 282. 40°N.—75°N.
„ marinus*, A. 241. 28° N.—56° N.
„ zonorhynchus, A. 212. 36° N.—56° N.
„ canus*, AUCT. *U. S.* —64° N.
„ Belcheri, VIG. N. *Pacif. coast.*
„ eburneus*, A. 287. 47° N.—75° N.
„ fuscus*, FRISCH. 218. *U. S.* BON. TEM.
„ tridactylus*, A. 224. 30° N.—74° N.
„ Bonapartii, A. 324. ?—70° N.
„ Franklinii, *F.B.A.* 71. ?—56° N.
„ capistratus*, *Baff. Bay*, TEM. 33° N.—74° N.
„ atricilla*, A. 314. ?—45° N.
„ ridibundus*, NAUM. 32, 44. *Greenl. seas.* TEM.
„ minutus*, FALK. *Voy.* 3, 24. *U.S.* BON. 65° N.
„ Sabinii*, A. 285. *Cal. Behr. St.* VIG. *Spitzb.* 36° N.—80° N.
„ Rossii*, *F.B.A. Newfoundland, Waigatz St. Spitzb., Regt. Inlet.* ?—82° N.

Rhynchops nigra, A. 323. ?—46° N.
Lestris parasiticus*, A. 267. 24° N.—75° N.
„ pomarinus, A. 253. 43° N.—67° N.
„ Richardsonii*, A. 272. 42° N.—75° N. (*parasiticus*, AUCT.)
„ cataractes*, *Brit. Zool.* 50, 6. *U. S.* BON.
„ Buffonii*, *enl.* 762. *U. S.* BON.
Diomedea exulans, A. 388. 35° S.—*U. S.* WILS. *Cape of Good Hope.*
„ fuliginosa, *col.* 469. *Cal. Aleut. islands*, VIG. 50° S.—50° N.
Procellaria glacialis*, A. 264. *U. S.*—60° N.
„ puffinus*, *enl.* 962. *U. S.*—60° N.
„ *obscura**, *St. degli Ucelli*, 538. *U. S.* BON.
Thalassidroma Wilsonii*, A. 270. 23° N.—55° N. BON. (*pelagica*, W.)
„ Leachii*, A. 260. 40° N.—55° N. BON.
„ pelagica*, A. 340. *U. S.*
„ Bullockii*, *Newfoundland.* AUD.

The *natatores*, like the *cetacea* which they represent, inhabit the waters, the majority seldom coming ashore except for the purpose of nidification; and they are mostly common to the two continents, especially the marine ones. The generic groups are almost entirely the same in the same parallels of latitude; and even where the species are peculiar, there is a surprising uniformity in the numbers of each group, as may be observed on consulting the table in page 167. The common white pelican of America is considered as distinct from the *onocrotalus* of the old world by Mr. Audubon, and some occasional differences in the bill are pointed out in the *Fauna boreali-americana*; but in most other respects the American and European pelicans have a very close resemblance. The breeding plumage of many of the northern gulls is still very imperfectly known, and the exact number of species and their distribution will remain uncertain until some ornithologist, who has the requisite opportunities of observation, accomplishes a revision of the genus. The characters of the black-headed gulls especially require elucidation.

In concluding our remarks on North American ornithology, made chiefly with a view of pointing out its peculiarities, by contrasting it with that of Europe, we may refer the reader to the Prince of Musignano's "*Specchio comparativo*"*, &c.,

* *Specchio comparativo delle Ornitologie di Roma e di Filadelfia, di* C. L. BONAPARTE, &c., *estratto dal No.* 33, *del nuovo giornale de' letterati.* Pisa, 1827.

for an excellent comparison of the birds inhabiting the middle parallels of the two zoological provinces.

The following table, which exhibits to an approximate fraction the proportion that each group of birds bears to the whole of the known North American species, will require correction as our knowledge of the ornithology of Mexico and the northern shores of the Pacific improves.

Groups.	No. of sp.	Prop. fr.	Groups.	No. of sp.	Prop. fr.
RAPACES	54	$\frac{1}{13}$	*Fissirostres*	23	$\frac{1}{30}$
Vulturidæ	5	$\frac{1}{138}$	Halcyonidæ	1	$\frac{1}{696}$
Falconidæ	35	$\frac{1}{20}$	Hirundinidæ	9	$\frac{1}{77}$
Strigidæ	14	$\frac{1}{50}$	Caprimulgidæ ..	4	$\frac{1}{174}$
INSESSORES	400	$\frac{4}{7}$	Trogonidæ......	9	$\frac{1}{77}$
Dentirostres	150	$\frac{3}{14}$	RASORES	33	$\frac{1}{21}$
Laniadæ........	45	$\frac{1}{15}$	Cracidæ........	3	$\frac{1}{232}$
Merulidæ	21	$\frac{1}{33}$	Columbidæ	12	$\frac{1}{58}$
Sylviadæ	73	$\frac{2}{19}$	Phasianidæ	1	$\frac{1}{696}$
Ampelidæ	9	$\frac{1}{77}$	Tetraonidæ	17	$\frac{1}{41}$
Muscicapidæ....	2	$\frac{1}{348}$	GRALLATORES	87	$\frac{1}{8}$
Conirostres	134	$\frac{5}{26}$	Tantalidæ	6	$\frac{1}{116}$
Fringillidæ	90	$\frac{2}{15}$	Ardeidæ........	16	$\frac{2}{87}$
Corvidæ........	20	$\frac{1}{35}$	Scolopacidæ	45	$\frac{1}{15}$
Sturnidæ	24	$\frac{1}{29}$	Rallidæ	9	$\frac{1}{77}$
Scansores	62	$\frac{1}{11}$	Charadriadæ	11	$\frac{1}{63}$
Picidæ	21	$\frac{1}{33}$	NATATORES	122	$\frac{2}{11}$
Psittacidæ	12	$\frac{1}{58}$	Anatidæ........	41	$\frac{1}{17}$
Ramphastidæ....	2	$\frac{1}{348}$	Colymbidæ	8	$\frac{1}{87}$
Cuculidæ	8	$\frac{1}{87}$	Alcadæ	15	$\frac{1}{46}$
Certhiadæ	19	$\frac{1}{37}$	Pelecanidæ	14	$\frac{1}{50}$
Tenuirostres.Trochil.	31	$\frac{1}{22}$	Laridæ	44	$\frac{1}{16}$

The whole zoological region of North America being accessible, without much difficulty, to naturalists and collectors, that highly interesting subject, the *migration of birds*, can be studied no where with greater advantage. The American ornithological works do, indeed, abound with scattered facts respecting the periodical flights of some species: and the introduction to the second volume of the *Fauna boreali-americana* contains a few general remarks on this matter; but a paper by the Rev. J. Bachman, published in Silliman's Journal for April, 1836, is the only one written expressly on the migration of North American birds which has come to my knowledge. In this treatise the movements of the feathered tribes in America are noticed

in a very agreeable and popular style; but there is a want of precise numerical data, which we trust Mr. Audubon's forthcoming volume will amply supply; in the mean time the following pages, containing the chief statements made in the works referred to, will give some idea of the question as it now stands.

The primary object of the migration of birds is generally allowed to be the obtaining a due supply of proper food in the various seasons of the year; and it is to be observed that in many cases the parents at the epoch of reproduction, and their callow young, require a very different kind of nourishment from that which the species subsists upon at other times; thus many, if not most of the hard-billed granivorous birds, feed their unfledged brood on soft insects and grubs.

Three lines of route, marked out by the physical features of the land, are pursued by the bands of migrating birds in their course through North America; some species retiring on the approach of winter through the eastern states and the peninsula of Florida to the West Indies; others passing down the great valley of the Mississippi to the Texas and eastern Mexico; and others again keeping to the westward of the Rocky Mountains, and entering the tropical regions by the shores of the Pacific. Some more widely-diffused species pursue all the three routes; while others, hitherto detected only in a single tract in the southerly part of their journey, spread from one side of the continent to the other as they approach their breeding quarters on the confines of the arctic circle. Many birds, and more especially the soft-billed waders, make their flight northwards in the higher latitudes through a different zone of country from that which they traverse on their return southwards, being influenced in this matter by the different conditions of the surface in spring and fall.

The short duration of summer within the arctic circle, taken in connexion with the time necessary to complete the process of incubation, the growth of plumage, and, in the case of the *anatidæ*, the moulting of the parent birds, serves to limit the northern range of the feathered tribes. The waders, which seldom make a nest, and the water-birds, which lay their eggs among their own down, and obtain their food on the sea or open lakes when the land is covered with snow, breed farthest north. The ptarmigans, which breed in very high latitudes, and moult during the season of re-production, migrate only for a short distance, and by easy flights; and, their food moreover being the buds or tips of willows and dwarf birch, can be obtained amidst the snow. When we consider that at the northern extremity of the American continent, and on the islands beyond it, the sum-

mer heat is already on the decline before the country is even partially denuded of its wintry mantle, we should scarcely expect to find any granivorous birds feeding in such high latitudes; but, in fact, by an admirable provision, springing from the peculiar severity of the climate, the snow-buntings and Lapland finches are furnished with food on their first arrival, when the patches of cleared land are scarcely larger than what suffices for the reception of their eggs. In the polar regions, the autumnal frosts set in so severely and suddenly that the process of vegetation is at once arrested, and the grass-culms, instead of whitening and withering as they do more to the southward, are preserved full of sap until the spring, the seeds remaining firmly fixed in their glumes; when the ground is prepared for their reception by the melting snow, the seeds fall, and in a few days, under the influence of continuous light, a brilliant, though short-lived, verdure gladdens the eye. These grass-seeds, then, and the berries of several *vaccineæ*, *empetreæ*, &c., which remain plump and juicy till the spring, yield food to the birds on their first arrival; and by the time that the young are hatched, their wants are supplied by the further melting of the snow liberating the larvæ of many insects. The *natatores*, which feed at sea, find open water early enough for their purpose, and it is interesting to observe how well even the freshwater *anatidæ* (the majority of which breed in high latitudes) are provided for. Long before the ice of the small lakes gives way it is flooded to the depth of several feet with melted snow, that swarms with myriads of the larvæ of gnats and other insects on which the ducks feed. The more herbivorous of the duck-tribe, viz., the geese, feed much on berries in their migrations; in the spring, before the sprouting of the tender grass, which they like, we find their crops filled with the shining, white, dry fruit of the *eleagnus argentea;* and in the autumn, when they cross the barren grounds, they banquet at their halting-places on the juicy berries of the *vaccinium uliginosum*, *vitis idæa*, or *empetrum nigrum*, which dye their crops a deep purple colour. These and other capabilities of the lands on the confines of the arctic circle account for so many birds entering the arctic fauna. The numbers of the *falconidæ* and *strigidæ* are of course proportioned to the abundance of smaller birds and rodent animals on which they feed.

It may be considered as a general rule, that the number of species of birds which enter the faunæ of successive parallels of latitude, diminishes gradually as we advance from the tropics towards the poles; but if we deduct the *birds of passage* and

accidental visiters, and conclude with some authors that the species properly belonging to a district are only those which breed within its limits, we shall then find that in North America the number of breeding birds increases as we go northwards, up to the 62nd degree of latitude, where the woods begin to thin off. Even on the verge of the barren grounds, near to the arctic circle, as many species breed as in the neighbourhood of Philadelphia, though in the latter locality some birds rear two or more broods in a season, which is not the case in the north. The Prince of Musignano states the number which hatch near Philadelphia, near the 40th parallel, at 113, while fourteen degrees farther north, at Carlton-house, on the Saskatchewan, the number amounts to 149, and the difference would no doubt be greater in favour of the latter place were its ornithology more thoroughly investigated; but all the species included in our estimate were detected in the course of a single spring by Mr. Drummond and myself.

The amount of species which reside the whole year in any one place has no direct relation to the numbers which breed there, but is regulated chiefly by the winter temperatures, or, in Humboldt's phrase, by the course of the isocheimal lines; and it seems evident that it is the diminution of supplies of food, and not the mere sensation of cold, which occasions birds to migrate from the high latitudes on the approach of winter. After the spring movement, the feathered tribes are often exposed in the fur countries to much lower temperatures than had occurred before their departure in autumn; and the eagle and other kinds which soar above the summits of the highest mountains, do not appear to be inconvenienced by the rapid change of climate to which they thus subject themselves. All the birds which feed on winged and terrestrial insects and worms, such as the fly-catchers, vireos, and warblers, must migrate from the northern regions, as well as most of the aquatic and piscivorous tribes, the suctorial tenuirostres, and all the grallatores, which thrust their bills into soft spungy soil in search of food. The wood-peckers, though insectivorous, are more stationary, because the larvæ of the xylophagous beetles, on which they subsist, lodging in trees, are as accessible in winter as in summer; but the *colaptes auratus*, which feeds mostly upon ants, and the *picus varius* quit the snow-clad fur-countries in winter, while they are permanent residents in the more southern districts.

The only bird seen at Melville Island, in latitude 75° N., during winter was a white one, supposed to be the *strix nyctea*, or it may have been a wandering *falco islandicus*, both these

birds preying on small quadrupeds. In the pools of water which remain open all the year in the arctic seas, the *uria grylle* and *Brunnichii* are to be found at the coldest periods, the *alcadæ*, consequently, are the most northerly winterers. Many individuals, however, of the species just named go far south in the winter season, and it has been observed that the old birds remain nearer the breeding stations, while the young seek their food further afield. This has been ascertained also of birds belonging to other families, and more especially of the *falconidæ* and *laridæ*, probably because their young are more readily known by their peculiar plumage. In the extreme northern parts of the continent the winter residents are the *falco islandicus* and *peregrinus*, *strix nyctea* and *funerea*, and the raven, all birds of prey, the *linaria borealis*, which in the winter time inhabits dwarf birch or willow thickets, and picks up a subsistence from the grass-spikes that overtop the snow, and the ptarmigan, whose mode of feeding has already been alluded to. The *strix lapponica* or *cinerea* and *virginiana*, *corvus canadensis*, *tetrao canadensis*, and *picus tridactylus*, inhabit the woods all the year up to their northern termination. The *tetrao canadensis* feeds on the evergreen leaves of the spruce-fir, and the *corvus canadensis*, which is omnivorous, is one of the few birds which lays up food for times of scarcity. As we proceed farther southwards, to the banks of the Saskatchewan for instance, we find large bands of willow ptarmigan (*tetrao saliceti*), which have left their breeding-quarters in the north to winter there, and the *tetrao phasianellus* and *umbellus*, which are permanent residents, also one or two species of *parus*, some additional woodpeckers, two *loxiæ*, the *pyrrhula enucleator*, the *corvus cristatus*, and two additional owls. The *emberiza nivalis*, which breeds between the 65th and 75th parallels, spends most of the winter on the Saskatchewan, being seldom absent more than two or three weeks in the severest weather, at which time it retires to the confines of the United States.

In the neighbourhood of Philadelphia we find 44 permanently resident birds, and 71 which come from the north to winter there, making together 115 winterers in that locality; in summer the 44 residents are joined by 74 species from the south, which breed in Pennsylvania, making in the aggregate 118 breeders; the rest of the birds enumerated in the Philadelphian fauna by the Prince of Musignano consist of 48 species, which merely pass through the district in spring and fall, on their way from their southern winter-quarters to their breeding-places in the north; the amount of species, residents and visiters, in that district being 281. Dr. Emmons enumerates 241

species in his list of Massachusetts birds, 126 of which breed within the limits of the state*. Out of 208 which were detected by us on the Saskatchewan, 146 species breed there, while the permanent residents and winter visiters do not exceed 25 or 30 species.

The following table, which is compiled from the Prince of Musignano's "*Specchio comparativo*", Dr. Emmons's list, and the *Fauna boreali-americana*, indicates the number of species that breed in three distant localities, the permanent residents, and those which come from the south in summer to breed being included in this number. A second column under each head comprises both the birds of passage and accidental visiters, these two classes not being easily distinguished in the present state of our knowledge of North American ornithology. A few observations on the several families follow the table.

Families.	Philadelphia. Lat. 40° N.		Massachusetts. Lat. 42½° N.		Saskatchewan. Lat. 54° N	
	Breed.	Pass.	Breed.	Pass.	Breed.	Pass.
Vulturidæ ...	1	1	...	...	...	1
Falconidæ ...	5	10	8	12	11	3
Strigidæ	3	6	7	3	9	1
Laniadæ	5	2	5	2	8	...
Merulidæ	8	...	5	4	6	2
Sylviadæ	9	32	15	14	11	3
Ampelidæ ...	6	1	4	1	3	1
Fringillidæ ...	16	16	14	14	15	5
Corvidæ	4	...	2	1	6	...
Sturnidæ	6	1	7	2	8	...
Picidæ	7	...	6	1	6	...
Cuculidæ	2	...	2	...	...	...
Certhiadæ ...	4	4	5	...	2	...
Trochilidæ ...	1	...	1	...	1	...
Halcyonidæ ...	1	...	1	...	1	...
Hirundinidæ ..	5	...	7	1	4	1
Caprimulgidæ.	2	...	2	...	2	...
Normal groups	85	73	91	55	93	17

Families.	Philadelphia. Lat. 40° N.		Massachusetts. Lat. 42½° N.		Saskatchewan. Lat. 54° N.	
	Breed.	Pass.	Breed.	Pass.	Breed.	Pass.
Columbidæ ..	2	...	1	1	1	...
Pavonidæ ...	1	...	1	...	...	...
Tetraonidæ ..	2	1	3	...	5	1
Tantalidæ ...	...	3	...	1	...	...
Ardeidæ	8	4	5	2	2	...
Scolopacidæ .	6	19	7	15	11	14
Rallidæ	3	3	2	3	2	...
Charadriadæ.	4	4	5	3	3	3
Anatidæ	3	28	2	19	14	16
Colymbidæ......	...	6	1	5	6	1
Alcadæ†	...	5	...	3	...	...
Pelecanidæ......	...	7	...	2	3	...
Laridæ	4	10	8	4	6	10
Aberrant groups	33	90	35	58	53	45

Rapaces.—The *vulturidæ*, as we have already mentioned, belong properly to the warm latitudes. Four of the five which

* List of the birds of Massachusetts, prepared by order of the State Legislature. By Ebenezer Emmons, M.D.

† The inland situation of Cumberland and Carlton-houses on the Saskatchewan excludes the alcadæ from their fauna.

enter North America are accordingly much more abundant to the south of the isthmus of Darien, and one only (*cathartes aura*) breeds as far north on the coast as Pennsylvania; in the interior this species reaches the 54th degree of latitude, but it is not known to breed there. Of the *falconidæ* named in our list, twelve range to South America, or have their head-quarters there, and as many have been detected in Mexico, where they are chiefly winter visiters, while the number that breed on the Saskatchewan is twice as great as in Pennsylvania: only two (*peregrinus* and *islandicus*), and these are of the typical group, winter in the fur-countries. The *strigidæ* are very partially migratory: *otus* and *brachyotus*, the only species which quit the fur-countries in winter, are resident all the year in the United States. Five of the North American owls belong also to the South American fauna.

Insessores, Dentirostres.—With a very few exceptions, confined, or nearly so, to the typical genus *lanius*, all the North American *laniadæ* retire in winter to Mexico, the West Indies, or South America, agreeing in this respect with the fly-catching *sylviadæ*, which they so closely resemble in their manner of taking their prey; the *tyrannulæ* especially are numerous in Mexico. The *merulidæ* wholly quit the fur-countries in winter, and all of them extend their migrations to Mexico, the West Indies, or South America, though detachments of some species, as *merula migratoria*, *orpheus polyglottus*, *rufus*, and *felivox* remain within the United States all the year: South Carolina is stated by the Rev. Mr. Bachman to be the most northerly winter range of the last-mentioned bird. The breeding-range of birds of this genus is very extensive; eight species perform that function in all parts of the United States, most of them going as high as the Saskatchewan. The *merula migratoria* is known to breed from North Carolina to the Arctic Sea; *cinclus americanus* and *orpheus nævius* breed in the higher latitudes only. Mr. Swainson has remarked of the American *sylviadæ* that they have their head-quarters in Mexico, and that while few species migrate towards South America, many go northwards on the approach of summer*. It is true that the Mexican fauna in-

* The Rev. Mr. Bachman, speaking of the neighbourhood of Charlestown, says, "The yellow-crowned warbler (*sylvia coronata*) is the only *sylvia* out of fifty species inhabiting the United States that remains with us in winter; and even this bird could not find subsistence in that season were it not that it almost changes its nature and lives on the fruit of the candle-berry myrtle (*myrica cerifera*). This is also the case with the only fly-catcher that winters in Carolina, viz., the peewee (*tyrannula fusca*), which sometimes fattens on the seeds of the imported tallow-tree (*stylingia cerifera*).

cludes many birds of this family, but many of them are hatched in the higher latitudes, to which, therefore, we consider them as properly belonging. Comparatively a small number spend the winter within the United States, more than half have been ascertained to enter the West India islands or Mexico, yet only one (the *setophaga ruticilla*) is known to pass the isthmus of Darien, so that there are few families in which the distinction between the North and South American faunæ are so evident. Of the few *ampelidæ* which belong to the North American fauna, *bombycilla carolinensis* and *vireo Bartramii* are known to visit South America. *Bombycilla garrula* breeds at the northern extremity of the continent, among the woods which skirt the Mackenzie; but its winter retreats are still unknown, though they are most probably in the Mexican cordilleras.

Insessores, Conirostres.—The *fringillidæ* is another family of which few species pass the isthmus of Darien from the northern continent; the *pyranga ludoviciana*, which attains the 42nd parallel in the interior prairies, and *saltator rufiventris*, which reaches the 36th on the coast of the Pacific, are the only ones common to the United States and South America. The *euphone jacarina*, also, and most probably some other Mexican species, enter the southern fauna. Many of the *fringillidæ* that breed in the high latitudes winter within the United States; some go to Mexico, and a few to the West Indies. The *emberiza nivalis* builds its nest on the most northern lands that have been visited, and the *alauda alpestris* and *emberiza lapponica*, likewise breed on the arctic coasts. The *corvidæ* are comparatively little migratory, and the majority inhabit limited districts of country, though two or three species are very widely distributed; none which enter the North American fauna are known to pass the isthmus of Darien. The *sturnidæ*, on the other hand, form a closer bond of union between the intertropical and northern faunæ; nearly all the North American species winter in Mexico or the West Indies, one, the *icterus spurius*, ranging as far south as Cayenne. The southern parts of the United States, however, are within the limits of the winter-quarters of *molothrus pecoris*, *scolecophagus ferrugineus* and *quiscalus major*, and *versicolor*. As cultivation advances in the fur-countries, the *sturnidæ* attract every year more and more the attention of the settlers on account of the havock they make in the corn-fields; but we are not prepared to assert that the range of this family of birds northwards is determined by the progress of agriculture. I am rather inclined to suppose that some individuals of the different species have always resorted to those latitudes to feed on the wild rice

(*zizania*) and other grass-seeds, but remained unnoticed in the marshes, until the labours of the husbandman providing them a more abundant repast, they made their appearance in the vicinity of the fur-posts. Mr. King, in his narrative of Captain Back's expedition, mentions that a flock of *scolecophagus ferrugineus* continued feeding on the offal of a fishery on Great Slave Lake, lat. 60½°, until late in December.

Insessores, Scansores.—The *picidæ,* or typical family of the *scansores,* are, as we have already mentioned, mostly residentiary, yet some of the species are distributed over forty degrees of latitude. In such cases, many individuals of a species may seek a more southern residence in winter, though the fact cannot be ascertained by consulting ornithological works, in which the migration of a bird is seldom noticed, unless it takes place in large flocks or entirely deserts the district; but it is undoubtedly true that near the northern limits of a resident species, the individuals are more numerous in summer than in winter. None of the North American *picidæ* have been detected in South America. The *cuculidæ* do not go to the northward of the valley of the St. Lawrence, only one species attaining that parallel; the majority of them certainly, perhaps the whole, are common to South America also. The *certhiadæ* abound in Mexico, and none of them go far north. The *troglodytes furvus,* or *aëdon,* which has the highest range, extends also furthest to the south, the species, according to the Prince of Musignano, being precisely the same in Surinam.

Insessores, Tenuirostres.—Of the *trochilidæ,* the only family of the tenuirostral tribe which detaches species northwards from Mexico, the *cynanthus colubris* breeds as high as the 57th parallel, on the eastern declivity of the Rocky mountains. The *trochilus anna,* according to Lesson, goes equally high on the coast of the Pacific, and Eschscholtz informs us that the *trochilus rufus* reaches the 61st degree of latitude on the same shore. The *lampornis mango,* a Brazilian species, has been detected recently on the peninsula of Florida in the 25th parallel, and the Reverend Mr. Bachman supposes that it is attracted thither by certain tubular flowers, lately introduced into the gardens in that quarter. This beautiful family of birds is numerous in Mexico, the physical conditions of that country ensuring them a constant succession of tubular flowers by short migrations from the low *tierras calientes,* which enjoy a tropical heat in winter, to the elevated plains and mountains as spring advances. Lichtenstein informs us that many of the Mexican humming birds pass the summer near the snow line, thus obtaining by a comparatively short flight a change of climate, which

their congeners above-named seek by traversing many degrees of latitude. Captain King observed some humming birds hovering over the *fuschiæ*, which grow plentifully in the Straits of Magalhaes, the ground being at the time covered withsnow.

Insessores, Fissirostres.—The only species of the *halcyonidæ* which enters North America, is universally distributed from Louisiana up to the 68th parallel: its winter being spent in the southern parts of the United States and in the West Indies. Few birds have given rise to more speculation than the swallows. Marvellous stories of their hybernating in caverns or at the bottoms of lakes, were believed even recently by naturalists of reputation, yet there is scarcely a seaman, accustomed to navigate the Mediterranean, who has not seen these birds migrating in large flocks to or from the coast of Africa, accompanied by predacious birds of various kinds. Mr. Audubon has skilfully availed himself of the great facilities which America offers for tracing the migrations of birds, so as to put to rest for ever the question of the hybernation of swallows. From his investigations, we are assured that the *hirundo bicolor* winters in the neighbourhood of New Orleans, where it roosts at night in hollow trees. Mr. Bachman also states, that this bird appears in the neighbourhood of Charlestown in winter after a few successive warm days. The other species winter in Mexico and the West Indies; and the *hirundo purpurea* and *riparia*, which extend in summer to the northern extremity of the continent, have a range southwards to the Brazils; the former it is stated by the Reverend Mr. Bachman breeding in the latter locality during the winter of the northern hemisphere. A conjecture that some species of birds might breed twice in the year in different climates was hazarded in the introduction to the *Fauna boreali-americana*, but I am not aware of any direct testimony to that effect having been adduced prior to the publication of Mr. Bachman's paper. The *caprimulgidæ* winter to the southward of the United States.

Rasores.—This is the least migratory of all the orders of birds, yet the species are in general readily acclimated in latitudes remote from their native haunts, and in fact it is from these birds that man derives the greatest advantage in his domestic economy. Our common poultry were originally brought from warmer regions, and this furnishes another evidence of abundance of proper food being more important than the temperature of the atmosphere in regulating the distribution of the feathered tribes, the dense covering of their bodies protecting them well from the severity of northern winters. There is, however, a limit to the range of each species, and it is found

that poultry thrive best in our climates when their coops are artificially heated in winter. The *tetraonidæ* are comparatively inhabitants of cold countries, and the ptarmigans, which are the most northern of all, are almost the only migratory ones. Most of these birds quit the bleak arctic barren lands in which they are bred, and retire in winter to the verge of the woods, returning, however, very early in spring to their former haunts, or as soon as the decreasing snow has released the tops of the dwarf birches and willows on which they feed, and the crests of a few gravelly banks. The passenger pigeon migrates northwards to the 62nd parallel, after its breeding season in the United States has terminated; through stress of weather individuals have been driven very far north, an instance being recorded by Sir John Ross, of the capture of one on the coast of Greenland. This pigeon visits Carolina in the winter at long and uncertain intervals, its arrival being determined, according to the Reverend Mr. Bachman, not by the severity of the season, but by the scarcity of food to the north: when beech mast is plentiful in Canada, it remains there in immense multitudes all the winter.

The *grallatores* are directly opposed to the *rasores* in being the most migratory order of birds. The *scolopacidæ* and several species of the other families breed in high latitudes, yet they winter within the tropics. In their migrations through the fur countries they pursue different routes in the spring and fall: thus at the time of the northern movement, the lateness of the summer on the coast of Hudson's Bay, and the quantity of ice which hangs on its shores till late in the year, exclude from that quarter the barges, snipes, and curlews which therefore pass by the interior prairies, where the melting snow has rendered the soil soft and spungy. In autumn again the prairies having been exposed to the action of a hot and generally very dry summer, are comparatively arid, but the late thaws on the coast flood the neighbouring flats even in August and September, and it is there accordingly that the soft-billed waders pass a month or six weeks on their way from their arctic breeding stations to the moist intertropical lands. The marshes and sand-banks in the estuaries of Hay, Nelson, Severn, and Moose rivers are resorted to in the fall of the year by immense flocks of strand birds. The following herons are stated by the Reverend Mr. Bachman to breed in Carolina, *ardea herodias, ludoviciana, candidissima, rufescens, cærulea, virescens, nycticorax, violacea,* and *exilis.*

Natatores.—The great majority of North American birds belonging to this order, breed to the north of the valley of the St. Lawrence, and are merely winterers or birds of passage in the middle states. The lakes of Mexico are the chief winter

resort of the *anatidæ*. The *anas boschas* has been found breeding from the lower part of the Mississippi up to the extremity of the continent, but in greatest abundance beyond the 50th parallel; and the *anser canadensis* from the 44th parallel to an equally high latitude, being also however most numerous in the fur countries. The rest of the geese and many of the ducks breed only within the arctic circle. The eider and king-ducks remain at sea in the high latitudes all the winter, the young only going southwards to the coast of Labrador and the United States. No others of the family winter higher than the 50th parallel in America, though several species remain at that season in Europe as high as the 60th degree of latitude.

The Reverend Mr. Bachman has made some observations on the effect of cultivation in influencing the movements of birds, but we think that he goes too far when he attributes the recent discovery of many new species within the limits of the United States solely to the changes produced in the face of the country, for the more general diffusion of accurate ornithological knowledge ought not to be overlooked. Thus among the examples of birds formerly rare but now common in the middle states, he quotes *hirundo lunifrons*, but this, (if identical with *fulva*, which is generally admitted,) was taken by Vieillot on the coast of New York, many years before the history compiled by Governor Clinton supposes it to have reached that state in its gradual advance from the interior; and the aborigines of the more northern countries have no tradition of a time when it did not breed on the perpendicular faces of their rocks. The singularity in its history is, that it should have so very recently begun to quit the rocks and to put itself under the protection of man, by building its nests under the eaves of houses. *Tyrannus borealis* (*muscicapa Cooperii* of Nuttall), *vireo solitarius* and *tringa himantopus*, also newly detected in the United States, breed in the uncultivated wastes of the fur countries.

The migration of the feathered tribes from the "*tierras calientes*" of the Mexican coast to the interior elevated plains and peaks, "*tierras templadas y frias*," presents within a smaller geographical range, as we have noticed in speaking of the humming birds, all the phenomena that take place in the extended flights from the intertropical regions to the arctic solitudes.

REPTILIA.

Catesby figured a portion of the North American animals of this class, but we are indebted to the labours of living naturalists

for the discovery of many more. These are described in the "Philadelphia Journal of Natural Sciences," the "Lyceum of Natural History of New York," "Silliman's Journal," and other periodical works, the chief writers being Messieurs Green, Say, Harlan, and Gilliams. A summary of the whole is contained in a paper by Dr. Harlan, entitled "Genera of North American Reptilia (including Amphibia), and a synopsis of the species," read in 1826 before the Philadelphia Academy, and subsequently reprinted, in a separate form with some alterations. Still more recently Dr. Holbrook of Charlestown has commenced a "North American Herpetology," which is to be completed in four quarto numbers, each containing from 20 to 30 coloured engravings and 200 pages of letter press. Wiegmann has also published a volume of his "*Herpetologia Mexicana*," embracing both *reptilia* and *amphibia*, having previously described many species in the Isis.

The warm, moist atmosphere of tropical America is very favourable to the existence of *reptilia*, which are more numerous there than in any other quarter of the world; and they occur even in North America, in much greater numbers and variety than in Europe. In the present imperfect state of North American herpetology, it would serve little purpose to attempt a formal disquisition on the distribution of the reptiles of that country, or to compare their numbers with those existing in the European zoological province, especially as these tasks may be performed with so much more success, when we become acquainted with the labours of Holbrook and Wiegmann. In the mean time we shall merely offer a few brief remarks. With the exception, perhaps, of one or two species of sea-turtles, none either of the *reptilia* or *amphibia* are common to the New and Old World; and it will be observed that the *reptilia*, though fewer in number in Europe, attain higher latitudes there than in North America. An *emys* inhabits the river Winipec in the latter country in the 50th parallel, but the *emys Europæa* goes some degrees further north in Prussia. The *crocodilus acutus*, which resembles the crocodile of the Nile so closely as to have been even mistaken for it, keeps within the tropics; it is an inhabitant of the West Indies and also of the Spanish Main, but to no great distance from the equator, for Humboldt believes that its northern limit is the peninsula of Yuccatan or the southern part of Mexico. Now, though crocodiles do not in the present day descend the Nile lower than Upper Egypt, they formerly inhabited the Delta at the mouth of that river, lying under the $31\frac{1}{2}°$ degree of latitude, where they were wont to pass the three winter months in burrows. In this respect they resemble the

alligator lucius or *Mississippiensis*, which attains the 32½° N. latitude, and in Georgia and Carolina winters in burrows. The *ophidia* swarm in the humid equatorial districts of America, but disappear on the acclivities of the Cordilleras, at an altitude of 6000 feet, and a mean annual temperature of 64° F. In the fur countries they reach the 55th parallel where the mean heat is about the freezing point, but where the temperature of the three summer months, during which only the serpents are visible, is at least 66° F. and very little inferior to the summer heat of the Mexican table lands. In Europe the isothermal line of 32° passes through the North Cape (lat. 71° 10½′ N.), and we find accordingly that some serpents (as the *coluber berus*) reach Norway. In like manner lizards (*lacerta ocellata*) exist in Kamtschatka and Sweden, though none of the saurians pass to the north of the 50th parallel in America. The following is a list of the genera of European and Egyptian reptiles, with the number of species noticed in Mr. Gray's synopsis, or the *Règne animal* given for the purpose of comparison with the subjoined table of North American ones. European reptiles: *Chelonia.*—Testudo 2; cistudo 1; emys 1; trionyx 1; sphargis 3. *Emydosauri.*—Crocodili 2. *Saurii.*—Monitor 2; lacerta 14; psammodromus 1; algyra 1. *Geckotidæ.*—Platydactylus 2; stenodactylus 1; thecodactylus 2; hemidactylus 2. *Iguanidæ.*—Agamæ 6. *Scincidæ.*— Scincus 1; tiliqua 2; anguis 1. *Zonuridæ.*—Ophiosaurus 1. *Ophidia.*—Trigonocephalus 2; vipera 1; berus 2; pelias 1; echis 1; naia 1; tropidonotus 5; coluber 6; coronella 3; dendrophis 1.

Obs.—The following list of American *reptilia* is compiled chiefly from Mr. Gray's synopsis in Griffith's translation of Cuvier, and will appear meagre and inaccurate after the publication of Wiegmann's and Holbrook's works. Species which do not range north of Mexico are in *Italics*.

Ord. I. CHELONIA.

Fam. Testudinidæ.

Testudo polyphemus, Bartr. 18.

Fam. Emydæ.

Cistudo carolina, Holb. 1.
Emys Muhlenbergii, Id. 5.
„ guttata, Schœpf. 31.
„ punctata, Holb. 4.
„ picta, Schœpf. 5.
„ speciosa, Id.
Emys concentrica, Schœpf. 15.
„ reticularia, Daud. 23, 3.
„ vittata,
„ decussata,
„ scripta, Schœpf. 3, 5.
„ serrata,
„ rugosa,
„ Troostii, Holb. 4.
„ Le Sueurii, Gray.
Kinosternon triporcatum, Wieg. 15. *Mex.*
„ *scorpioides*, Shaw, 15. *Mex.*
„ pennsylvanicum, Edw. 287.
„ odoratum, Daud. 24, 3.
Chelydra serpentina, Schœpf. 6.

Fam. Trionychidæ.

Trionyx ferox, Schœpf. 19, 12, 3.
„ muticus, Le Sueur. *Mem. Mus.* 15, 257.

Fam. Cheloniadæ.

Sphargis imbricata, Schœpf. 18, a.
„ mydas, Id. 17, 1.
„ caretta, Id. 16.

Ord. II. EMYDOSAURII.

Fam. Crocodilidæ.

Crocodilus rhombifer, Wieg. *W. Ind. Mex.*
Alligator lucius, Cuv. *An. Mus.* X. *Georg. Mississ.*

Ord. III. AMPHISBÆNIÆ.

Chirotes lumbricoides, Lacep. 41. *Mex.*

Ord. IV. SAURII.

Holoderma horridum, Wagler, 2, 18. *Mex.*

Fam. Geckotidæ.

Platydactylus americanus, Gray. *New York.*

Fam. Iguanidæ.

Iguana tuberculata, Spix. 6, 8. *S. Am. Mex.*
Amblyrhynchus cristatus, Wieg. *Mex.*
Ctenosaura cycluroides, Wieg. *Mex.*
„ cyclura, Cuv. *Carol.*
Cyclura carinata, Harl. *Ph. Ac. Sc.* 4, 15. *Bahamas.*
„ *teres*, Id. *Tampico.*
„ *pectinata*, Wieg. *Mex.*
„ *articulata*, Id. *Mex.*
„ *denticulata*, Id. *Mex.*
Læmanctus longipes, Wieg. *Mex.*
Ophyessa umbra, Daud. *Calif.*
Scelephorus undulatus, Wieg. *U. St.*
„ *torquatus*, Wieg. *Isis*, 21. *Mex.*
„ *formosus*, Wieg. *Mex.*
„ *spinosus*, Id. *Mex.*
„ *horridus*, Id. *Mex.*
„ *grammicus*, Id. *Mex.*
„ *microlepidotus*, Id. *Mex.*
„ *variabilis*, Id. *Mex.*
„ *æneus*, Id. *Mex.*
„ *scalaris*, Id. *Mex.*
„ *pleurostictus*, Id. *Mex.*
Phrynosoma Douglasii, Bell. *Lin. Tr. N. Calif.*
Phrynosoma cornutum, Harl. *Ac. Sc. Ph.* 20. *Western prairies.*
„ *orbiculare*, Wieg. *Mex.*
Chamælopsis Hernandesii, Wieg. *Mex.*
Anolius podargicus, Cat. 66. Holb. 7. *Carol.*
„ bimaculatus, *W. Ind. U. S.*
„ *bullaris*, Lacep. 27. *W. Ind. Mex.*
„ *nebulosus*, Wieg. *Mex.*
„ *læviventris*, Wieg. *Mex.*
„ *biporcatus*, Id. *Mex.*
„ *Schiedii*, Id. *Mex.*

Fam. Teidæ.

Ameiva cæruleocephala, Seba. 91, 3.
„ tessellata, Say. *Long. Exp. Ark.*
„ collaris, Id. *Ark.*
Cnemidophorus undulatus, Wieg. *Mex.*
„ *Deppii*, Id. *Mex.*
„ *Sackii*, Id. *Mex.*
„ *guttatus*, Id. *Mex.*

Fam. Scincidæ.

Tiliqua quinquelineata, Cat. 67. *Mex.* (Wieg.) *Carol.*
„ erythrocephala, Gill. *Ac. Sc. Phil.* 1, 18, 2.
„ lateralis, Say. Holbr. 8. *West. st.*
„ bicolor, Harl. *Ac. Sc. Phil.* 4, 18, 1.
Bipes anguinus, Id. *l. c.* 4, 10. f. 1. *Carol.*
Corythaelus vittatus, Wieg. *Mex.*

Fam. Zonuridæ.

Gerrhonotus Deppii, Wieg. *Is.* 21. *Mex.*
„ *imbricatus*, Id. *l. c. Mex.*
„ *leiocephalus*, Id. *l c. Mex.*
„ *tæniatus*, Id. *l. c. Mex.*
„ *tessellatus*, Id. *l. c. Mex.*
„ *rudicollis*, Id. *l. c. Mex.*
Ophisaurus ventralis, Cat. 59. *U. S.*

Ord. V. OPHIDIA.

Crotalus horridus, Cat. 41. *S. Am. Mex. U. S.*
„ durissus, Spix. 24. *S. Am.*—45° N.
„ miliaris, Cat. 42. *Carol.*
„ tergeminus, Say. *West. st.*
„ confluentis, Id. *R. Mount.*
„ *triseriatus*, Wieg. *Mex.*
Cenchris mockeson, Cat. 45.
Tisiphone Shausii, Gray. *S. Am. Carol.*
Trigonocephalus cacodema, Cat. 44. *Carol.*
Scytale piscivorus, Harl.
„ *cupreus*, Id.
Heterodon constrictor, Cat. 76. *Carol.*

Tropidinotus porcatus, CAT. 46. *Carol.*
„ ordinatus, CAT. 53. *Carol. & R. Mount.*
„ proximus, SAY. *Missouri.*
„ parietalis, ID. *Missouri.*
„ fasciatus, SHAW. *S. St.*
„ sirtalis, *Penns.*
„ saurita, CAT. 50. *S. St.*
„ sipedon, HARL. *Mid. St.*
Coluber punctatus, LIN.
„ getulus, CAT. 52. *S. Carol.*
„ obsoletus, HARL.
„ testaceus, ID. *Missouri.*
„ filiformis, ID. *Carol.*
„ flagelliformis, ID. *Carol.*
„ flaviventris, ID. *Missouri.*
„ striatulus, ID. *Carol.*
Coluber amœnus, HARL. *Penns.*
„ rigidus, ID. *S. St.*
„ septemvittatus, ID. *Penns.*
„ coccineus, ID. *Carol.*
„ æstivus, ID. *Carol.*
„ getulus, ID. *Carol.*
„ calligaster, ID. *Missouri.*
„ melanoleucas, ID. *N. Jersey.*
„ eximius, ID. *Penns.*
„ vernalis, ID. *Penns. N. Jers.*
„ cauda-schistosus, ID.
„ doliatus, ID. *Carol.*
„ maculatus, ID. *Louis.*
„ guttatus, ID. *Carol.*
„ molossus, ID. *Carol.*
„ reticularis, ID. *Louis.*
Xenodon punctatum, LATR. *S. Carol.*

AMPHIBIA.

RANA.

Rana pipiens, CAT. *Mid. St.*
„ clamitans, BOSC. *Ditto.*
„ melanota, RAF. *L. Champl.*
„ halecina, CAT. *Penn. & S. St.*
„ flavi-viridis, HARL. *Mid. St.*
„ sylvatica, ID. *Ditto.*
„ palustris, ID. *Ditto.*
„ pumila, LE CONTE.
„ gryllus, HOLBROOK. *Flor. Mid. St.*
„ nigrita, LE CONTE.
„ ocellata, SHAW 34. *Mex. Florid.*
Hyla lateralis, CAT. *Surin. Carol.*
„ femoralis, DAUD. *S. St.*
„ squirella, DAUD. *S. St.*
„ delitescens, LE CONTE. *Georgia.*
„ versicolor, ID. *Mid. & S. St.*
Bufo clamosus, CAT. *Ditto.*
„ cognatus, SAY. *Long's Exp. Miss.*
„ fuscus, *Penn.*

SALAMANDRA.

Salamandra subviolacea, CAT. 10. *Penn.*
„ tigrina, GREEN, *New Jers.*
„ rubra, DAUD.
„ variolata, GILLIAMS, *Ac. Sc. Ph.* 1, 18, 1.
„ cylindracea, HARL. *N. Carol.*
„ frontalis, *N. Jers.*
Salamandra fusca, GREEN. *N. Jers.*
„ dorsalis, HARL. *Carol.*
„ picta, HARL. *Penn.*
„ Beechii, GRAY.
„ maculata, GREEN. *N. Jers.*
„ subfusca, ID. *Ditto.*
„ longicauda, ID. *Ditto.*
„ nigra, ID. *Penn.*
„ flavissima, HARL. *Ditto.*
„ Greenii, GRAY.
„ erythronota, GREEN.
„ cinerea, GREEN.
„ fasciata, GREEN.
„ glutinosa, GREEN. *New Jers.*
„ symmetrica, HARL. *Carol.*
„ cylindracea, HARL. *Carol.*
„ *platydactyla*, CUV. *Mex.*
Menobranchus lateralis, HARL. *An. Lyc.* 1, 16. *L. Champl. Ohio.*
„ alleghaniensis, SAY. *Griff. Cuv.*
Phyllhydrus pisciformis, SHAW 140. *Mex.*
Amphiuma means, *An. Lyc.* 1, 22. *Carol. Mex.*
„ tridactylum, CUV. *Louis.*
Siren lacertina, LIN. *S. St.*
„ intermedia, LE CONTE. *S. St.*
„ striatus, ID. *An. Lyc.* 1, 2.
Menopoma gigantea, HARL. *An. Lyc.* 1, 17. *Ohio*

Note.—In the above list, *rana scapularis*, HARL., is considered as the young of *pipiens*, and *rana gryllus* and *dorsalis* of Le Conte as one species. *Salamandra rubriventris*, GREEN, is considered the same with *rubra; sinciput-albida*, GREEN, the same with *frontalis; intermixta*, GREEN, the same with *picta*, and *variegata* of Gray with *platydactylus*. *Salamandra porphyritica*, *Jeffersoniana*, and *cirrhigera* of Harlan's list, being very doubtful species, are omitted.

Our remarks on the *amphibia* will be still more brief than on the reptiles. Some *amphibia* are evidently more capable of enduring extremes of temperature than the *reptilia*, and they exist in higher latitudes; frogs and salamanders reaching the 67th parallel on the Mackenzie, where the mean temperature is not above 7 or 8 degrees of Fahrenheit, and the winter colds sometimes descend to more than 90° below the freezing point. Spallanzani relates that living frogs have been seen in the thermal baths of Pisa, which have a temperature of 115° F. In the fur countries the pools of melting snow swarm with very noisy frogs long before the soil is thawed; the office of reproduction is performed and the pools dried up by the time that the ice of the lakes is dissolved, and before the earth is sufficiently warmed to permit the snakes to crawl forth from their subterranean retreats. The principal genera *rana, bufo, hyla,* and *salamandra* occur both in Europe and North America. The genera *siren* and *menopoma* belonging to the latter country, are perfectly amphibious, the mature animals possessing both lungs and gills, and respiring at pleasure either air or water. The only analogous animal of the Old World is the *proteus anguinus* of the lakes of Lower Carniola, and the grotto of Adelsberg, between Trieste and Vienna. I observed on the banks of the Mackenzie a very singular looking tadpole which swarmed in a pool of water in the spring. It was about the size of a man's thumb, and its abdomen was greatly distended with fluid, but its integuments were quite transparent, and so tender that they burst on the slightest touch. Circumstances did not admit of my describing it at the time, and the specimens put into spirits were destroyed by accident.

PISCES.

The ichthyology of North America has not hitherto been attended to as it merits, and the distribution of the species through a very large portion of the northern hemisphere is still almost unknown. Catesby, Pennant, and Schœpf are the chief authorities of older date, for the introduction of the American fish into the systems, but the Linnean genera are so ill adapted for the reception of many of the forms peculiar to the New World, and the specific descriptions of the old writers are so brief and indeterminate, that the labours of these naturalists are often altogether unavailable to modern cultivators of science. Le Sueur, the most accurate of recent American ichthyologists, has described many species in the "Journal of the Academy of Sciences of Philadelphia," in the new series of the "Trans-

actions of the Philosophical Society" of the same city, and in the "*Museum d'Histoire Naturelle*" of Paris. Dr. Mitchill published a paper on the New York fish in the first volume of the "Transactions of the Philosophical Society of New York," but his descriptions are almost always imperfect, and often inaccurate, and he has arranged the species without judgement in Linnean genera, so that but for the accompanying figures it would be difficult to recognise the fish he mentions. Rafinesque-Smaltz gave to the world a crude synopsis of the fish of the Ohio, proposing many new genera, but characterising them with so little skill, that there is little chance of their being adopted by future naturalists. His species are printed in the subjoined lists in italic characters, as being doubtful. The third volume of the *Fauna boreali-americana* is devoted to the northern fish, and contains a considerable proportion of the species which inhabit the fresh waters of the fur countries: it is, however, very deficient in marine fish, and even in the fresh water ones of New Caledonia and Canada, owing to the author's attempts to procure specimens from these countries having failed. The admirable *Histoire des Poissons* by Cuvier and Valenciennes embraces all the determinable species noticed by preceding naturalists, but it has not yet advanced beyond the *acanthopterygii*, the untimely death of its great projector having retarded its progress. The arrangement of this work is followed in the subsequent lists of species. In it and in the *Règne animal* 16 families of acanthopterygian fishes are indicated. All these families are represented by a greater or smaller number of species both in Europe and America, with the exception of the *anabasideæ*, none of which exist in the waters of either country; of the *acanthurideæ* which do not occur in Europe; and of the *tænioideæ*, which, as restricted in the *Histoire des Poissons*, have not been detected in America. All the families of *malacopterygii* and *chondropterygii* enter the *faunæ* of both countries, with the exception of the *sauroideæ* of Agassiz, which do not exist in Europe. The only fresh water fish which is unequivocally common to the two continents is the common pike, (*esox lucius*,) and it is curious that this fish is unknown to the westward of the Rocky Mountains, on the very coast that approaches nearest to the old continent. Several other European fresh water fish occur in the lists given by American ichthyologists, but more rigid comparisons are required to sanction their application of the names. Some of the anadromous *salmonoideæ* and *clupeoideæ* are more likely to be common to both sides of the Atlantic, but even these require further investigation. The curiosity of naturalists has been considerably ex-

cited by the noises which certain fishes have the power of making, and some facts are stated in the *Histoire des Poissons* relating to this subject in the chapters devoted to the *cottoideæ, sciænoideæ*, &c. Several kinds of fish vulgarly named "grunts" in America, possess this faculty in an extraordinary degree, and the purpose it is intended to serve, and the manner in which the sound is produced, are worthy of investigation by naturalists residing where these fish abound*. Every mariner who has anchored early in the spring on the coasts of South Carolina, Georgia, or Florida, must have been annoyed by a drumming noise, produced in the night, apparently on the bottom of the ship, and loud enough to deprive a stranger of rest, until habit has rendered the sound familiar. This noise is said to be caused by a fish of about six pounds weight beating its tail against the vessel to relieve itself from the pain caused by multitudes of parasitic worms which infest it at that season.

In dividing the ocean into zoological districts to suit our present knowledge of species of fish and their distribution, we have found the nine following divisions to be convenient. European seas,—North American Atlantic and Arctic sea,—Caribbean sea and South American Atlantic,—African Atlantic,—Indian Ocean, Red Sea, and Polynesian Sea,—Australian seas,—Seas of China and Japan,—Sea of Kamtschatka and North-west America,—Pacific coast of South America. In a preceding part of the Report we stated that Mr. Swainson had justly included the North of Africa in the European zoological province, as far as birds were concerned, but the case is different with the fish. The whole of the Mediterranean fish indeed are European, but the fish of the Nile have very little resemblance to those of the European rivers, while the same species often occur on the coast of Senegal and in the Red Sea. The anadromous fish of the Mississippi and its tributaries are very different from those which enter the North American rivers falling into the Atlantic, in the same parallels of latitude.

As in the preceding lists, the species whose names or history are doubtful are printed in italics, as are likewise the Mexican fish which do not range further northwards.

ACANTHOPTERYGII.

Fam. PERCOIDEÆ.

Perca flavescens, Cuv. *New Y.—L. Huron.*
,, serrato-granulata, Cuv. *N. York.*
,, granulata, Cuv. *N. York.*
,, acuta, Cuv. *L. Ontario.*
Perca gracilis, Cuv. *N. York.*
,, *Plumieri*, Cuv. *Bahamas.*
Labrax lineatus, Cuv. *N. York.*
,, *notatus*, *F. B. A. St Lawr.*

* *Vide* AUDUB. *Orn. Biogr.* 3, p. 199.

Labrax mucronatus, Cuv. *Caribb. S.—N. York.*
„ multilineatus, Cuv. *Wabash r.*
Pomacampsis nigro-punctata, Raf. *Ohio.*
Lucioperca americana, Cuv. 40° N.—58° N.
„ *canadensis*, H. Smith, *Griff. Cuv. St. Lawr.*
Huro nigricans, Cuv. *L. Huron.*
Serranus fascicularis, Cuv. *Braz.—Carol.*
„ morio, Cuv. *N. York.*
„ acutirostris, Cuv. *Carol.—Braz.*
„ ——— ? Benn. *San Blas. Pacif.*
Centropristes nigricans, Cuv. *N. York.*
„ trifurcus, Cuv. *Carol.*
Grystes salmoides, Cuv. *Wabash. Rivers of Carol.*
Stizostedion salmoneum, Raf. *Ohio.*
Centrarchus æneus, Cuv. *L. Ontario & Huron.*
„ pentacanthus, Cuv. *Carol.*
„ hexacanthus, Cuv. *Carol.*
„ irideus, Cuv. *Carol.*
„ gulosus, Cuv. *L. Pontchartr.*
„ viridis, Cuv. *Ditto.*
Pomotis vulgaris, Cuv. *Philad.—L. Huron.*
„ Ravenelii, Cuv. *Charlestown.*
„ Holbrookii, Cuv. *Carol.*
Pomotis incisor, Cuv. *L. Pontchartr.*
„ gibbosus, Cuv. *Carol.*
„ solis, Cuv. *L. Pontchartr.*
„ Catesbei, Cuv. *Penns.*
Bryttus punctatus, Cuv. *Ohio.*
„ reticulatus, Cuv. *Carol.*
„ unicolor, Cuv. *Carol. Penns.*
Ichthelis cyanella, Raf. *Ohio.*
„ *melanops*, Id. *Ohio.*
„ *erythrops*, Id. *Ohio.*
„ *aurita*, Id. *Ohio.*
„ *megalotis*, Id. *Ohio.*
Pomoxis annularis, Id. *Ohio.*
Aplocentris calliops, Raf. *Ohio.*
Lepibema chrysops, Raf. *Ohio.*
Aphrodederus gibbosus, Lesueur. *L. Pontch. Penns.*
Trichodon Stelleri, Cuv. *Unalasch.* Gilliams.
Holocentrum longipinne, Cuv. *Braz.—Carol.*
Uranoscopus anoplos, Cuv. *Massach.* Smith.
Sphyræna barracuda, Cuv. *Bahamas.*
Polynemus tridigitatus, Cuv. *New Y.* Mitch.
„ approximans, Benn. *San Blas.*
Upeneus punctatus, Cuv. *Caribb. s. Mex.*

Fam. Cottoideæ.

Trigla pini*, Bl. *New Y. Europe.*
Prionotus strigatus, Cuv. *N. York.*
„ carolinus, Cuv. *N. York. Massach.*
„ tribulus, Cuv. *N. York.—Carol.*
Dactylopterus volitans*, Lac. *G. of Mex. Newfound.*
Cottus cognatus, *F. B. A. Arct. Am.—Greenl. ?*
„ *gobio* ? Smith. *Massach.*
„ *quadricornis ?* Id. *Do.*
„ polaris, Sabine, *Parry's Is.* 75N°.
„ *hexacornis*, *F.B.A.* Polar sea.
„ octodecim spinosus, Mitch. *Virg.—N. York.*
„ groenlandicus, *F.B.A.* 95, 2. *Newf.—Greenl.*
„ polyacanthocephalus, Pall. *Cape St. Elias.* 60° N.
„ scorpioides, Fabr, *Greenl.*
„ *Mitchilli*, Cuv. *N. York.*
„ *æneus*, Mitch. *N. York.*
„ porosus, Cuv. *Baffin's Bay.*
„ pistilliger, Cuv. *Unalaschka.*
Aspidophorus europæus*, Cuv. *Greenl. Mass.* Smith.
Aspidophorus accipenserinus, Cuv. *Unalaschka.*
„ monopterygius, Cuv. *Greenl.*
Hemitripterus americanus, Cuv. *N. York.—Newf.*
Hemilepidotus Tilesii, Cuv. *Unalasch.—Ochotsk.*
„ asper, *F.B.A.* 95, 1. *Columbia R.*
Temnistia ventricosa, Esch. 13. *Norfolk sound Pacif.*
Scorpæna porcus*, L. *N. York.—Europe.*
„ bufo, Cuv. *Braz.—Newf.* Aud.
Sebastes norvegicus*, Cuv. *Newf.—Greenl.*
„ variabilis, Cuv. *Unalasch.*
Blepsias trilobus, Cuv. *N. W. Coast.*
Gasterosteus concinnus, *F.B.A. Arctic Am.*
„ noveboracensis, Cuv. *New Y.*
„ niger, Cuv. *Newf.*
„ biaculeatus, Penn. *New Y.*
„ occidentalis, Cuv. *Newf.*
„ quadracus, Mitch. *N. York.*
„ apeltes, Lesueur, *U. St.*
„ *kakilisak*, Fabr. *Greenl.*

Fam. SCIÆNOIDEÆ.

Otolithus regalis, CUV. *Carrib. s.—N. York.*
„ Drummondii, *F.B.A. Texas.*
„ carolinensis, CUV. *Carol.*
Corvina argyroleuca, CUV.
„ Richardsonii, *F.B.A.77. L.Huron.*
„ oscula, CUV. *L. Ontario.*
„ grisea, LE SUEUR, *Ac. Sc. Ph.* 2, 251. *Ohio.*
„ multifasciata, ID. *l. c. Florida.*
Lepomis pallida, RAF. *Ohio.*
„ *trifasciata*, ID. *Do.*
„ *flexuolaris*, ID. *Do.*
„ *salmonea*, ID. *Do.*
„ *notata*, ID. *Do.*
„ *ichtheloides*, ID. *Do.*
Leiostoma humeralis, CUV. *Penns.—N. York.*
„ xanthurus. CUV. *Carib. s.—Carol.*
Amblodon grunniens, RAF. *Ohio.*
Etheostoma calliura, RAF. *Ohio.*
„ *flabellata*, ID. *Ohio.*
„ *nigra*, ID. *Ohio.*
„ *blennioides*, ID. *Ohio.*
„ *caprodes*, ID. *Ohio.*
„ *fontinalis*, ID. *Ohio.*
Umbrina alburna, CUV. *G. of Mex.—N. York.*
Pogonias chromis, CUV. *Montiv.—N. York.*
„ fasciatus, LACEP. *N. York.*
Pogostoma leucops, RAF. *Ohio.*
Micropogon lineatus, CUV. *Montiv.—N. York.*
„ *undulatus*, CUV. *G. of Mex.*
Hæmulon arcuatum, CUV. *Carol.*
„ chrysopteron, CUV. *N. York.*
Pristipoma fasciatum, CUV. *N. York.*
„ rodo, CUV. *N. York.*
Lobotes surinamensis, CUV. *Sur.—N. York.*

Fam. SPAROIDEÆ.

Sargus ovis, CUV. *G. of Mex.—N. York.*
„ rhomboides, CUV. *Do. Do.*
Chrysophrys aculeata, CAT. 31, 2. *U. St.*
Pagrus argyrops, CUV. *Carol. N. York.*
Dentex ———? BENN. *San Blas. Pacif.*

Fam. MÆNOIDEÆ.

Gerres aprion, CUV. *Carib. s. Mex.—Carol.*

Fam. CHÆTODONTOIDEÆ.

Ephippus faber, CUV. *N. York.*
„ gigas, CUV. *Do.*
Holocanthus ciliaris, LACEP. *Mex. Carib. s.—Carol.*
Pimelepterus Boscii, LACEP. *Carol.*

SCOMBEROIDEÆ.

Scomber grex*, } MITCH. *N. York. Mass.*
„ vernalis, } MITCH. *N. York. Mass.*
„ *scomber*, SMITH. *Massach.* ?
*Thynnus vulgaris**, CUV. *Mass.* ? SMITH.
Pelamys sarda, CUV. *N. York.*
Cybium maculatum, CUV. *Mex.—Mass.*
Trichiurus lepturus, CUV. *Braz.—N. York.*
Xiphias gladius, SMITH. *Mass.* ?
Naucrates ductor*, CUV. *N. York. Mass. —Eur.*
Elecate atlantica, CUV. *Braz.—N. York.*
Trachinotus *glaucus*, CUV. *Carib. s.—Mex.*
„ fusus, CUV. *Braz.—N. York.* MITCH.
„ argenteus, CUV. *N. York.*
„ pampanus, CUV. *Mex.—Carol.*
Notacanthus nasus, CUV. *Greenland.*
Caranx punctatus, CUV. *Carib. s.—N. York.*
„ *chrysos*, CUV. *Massach.* ? SMITH.
„ *fasciatus*, CUV. *Mex.*
Argyreyosus vomer, LACEP. *Braz.—N. York.* 35°S.—45° N.
Vomer Brownii, CUV. *Braz.—N. York.* 35° S.—45° N.
Seriola Boscii, CUV. *Carolina.*
„ fasciata, CUV. *Do.*
„ leiarcha, CUV. *Penns.*
„ zonata, CUV. *N. York.*
„ cosmopolita, CUV. *Braz.—New York.*
„ *falcata*, CUV. *Carib. s.—Mex.*

Seserinus alepidotus, Massach.? Smith.
Temnodon saltator*, Cuv. *Braz.—Mass. —Eur.*
Coryphæna Sueurii, Cuv. *Penns.*
Pteraclis carolinus, Cuv. *Carol.*
Rhombus longipinnis, Cuv. *Carol.—N. York.*
„ cryptosus, Cuv. *N. York.*
Zeus faber, Massach.? Smith.
*Lampris guttatus**, Retz. *Greenl.—Mass.?*

Fam. Acanthuroideæ.

Acanthurus phlebotomus, Cuv. *Carib. s. N. York.*
Acanthurus cæruleus, Cat. 2, 10, 1. *Bahamas.*

Fam. Atherinideæ.

Atherina carolina, Cuv. *Carol.*
„ Boscii, Cuv. *Do.*
„ mænidia, L. *N. York.*
„ *Humboldtiana*, Cuv. *Mex.*
Atherina vomerina, Cuv. *Mex.*
„ *mordax*, Mitch. *N. York.*
„ *viridescens*, Id. *Do.*

Fam. Mugiloideæ.

Mugil Plumieri, C. & V. *Braz.—New York.*
„ albula, L. *N. York.* Mitch. *Mass.* Smith.
Mugil petrosus, C. & V. *Braz.—G. of Mex. N. York.*
Mugil lineatus, Mitch. *N. York.*
„ ———? Benn. *San Blas.*

Fam. Gobioideæ.

Blennius geminatus, Wood. *Ac. Sc. Ph. Carol.*
„ punctatus, Wood. *l. c. Carol.*
Pholis carolinus, C. & V. *Carol.*
Chasmodes Bosquianus, C. & V. *N. York.* Mitch.
„ quadrifasciatus, Wood. *Ac.Sc.Ph. Baltimore.*
„ novemlineatus, Wood. *l. c. Carol.*
Clinus? hentz, Le Sueur. *Carol.*
Gunnellus vulgaris*, C. & V. *Greenl. Eur.*
„ mucronatus, C. & V. *N. York.*—Mitch.
„ punctatus, C.&V. *Newf.—Greenl.*
„ Fabricii, C. & V. *Greenl.—Fabr.*
„ anguillaris, C. & V. *Kamtsch.—N. W. Am.*
„ dolichogaster, C. & V. *Aleut. Isl.*
Gunnellus groenlandicus, C. & V. *Greenl.*
Zoarces labrosus, C. & V. *N. York.* Mitch.
„ fimbriatus, C. & V. *Do.* Id.
„ *Gronovii*, C. & V. *N. Am.*
„ *polaris**, Rich. *Polar seas.*
Anarhichas lupus*, L. *Greenl.—Eur.*
Gobius Boscii, Lac. *Carol. N. York.* Mitch.
Philyprinus dormitator, C. & V. *W. Ind.—Mex.*
Chirus monopterygius, Cuv. *Mem. Pet.* 2, 23, 1. *Unalasch.*
„ decagrammus, Cuv. *l. c.* 2, 22, 2. *C. St. Elias.*
„ octogrammus, Cuv. *l. c.* 2, 23, 2. *Aleut. Is.*
„ superciliosus, Cuv. *l. c.* 2, 23, 3. *Unalasch.*

Fam. Batrachoideæ.

Lophius americanus, C. & V. *Penns.—N. York.* Mitch.
Chironectes lævigatus, C. & V. *Carol.—N. York.* Mitch.
Malthæa vespertilio, C. & V. *Carib. s.—Newf.*
„ cubifrons†, *F.B.A.* 96. *Newf.*—Audub.
Malthæa notata, C. & V. *N. York.*
Batrachus tau, C. & V. *G. of Mex.—N. York.*
„ *Gronovii*, C. & V. *C. of America.*
„ *grunniens*, Schœpf. *N. York.*

† M. Valenciennes considers this species to be identical with one figured by Seba, and named by Cuvier *malthæa nasuta*; but I can scarcely conceive that it could be possible for any painter to err so far as to give a tapering snout to a fish like *cubifrons*, which has nothing like a snout at all, but merely a round tubercle, like a grain of shot in the middle of a square forehead.

Fam. LABROIDEÆ.

Labrus americanus, BL. *N. York.* MITCH. *Mass.* SM.
„ *coricus*, SMITH. *Mass.*
„ *pallidus*, MITCH. *N. York.*
„ *hiatula*, L. *Carol.* GARDEN.
Cheilinus radiatus, BL. SCHN. 56. *U. St.*
Lachnolaimus suillus, CAT. 2, 15. *Baham.*
Crenilabrus burgall, MITCH. 3, 2. *N. York.*
„ *merula*, SMITH. *Massach.*
„ *exoletus*, L.? *Greenl.?* FABR.
Xirichthys psittacus, CUV. *Carol.*
„ lineatus, CUV. *Do.*
Scarus Catesbei, CAT. 2, 29. *Bahamas.*
„ *cœruleus*, CAT. 2, 13. *Do.*

Fam. FISTULAROIDEÆ.

Fistularia tabacaria, BL. 387, 1. *N. York. Mass.*
„ serrata, CAT. 2, 17. *Baham. U. S.*
Fistularia neo-eboracensis, MITCH. 3, 8. *N. York.*

Percoideæ.—Of 500 species belonging to this family, which are described in the *Histoire des Poissons*, two-thirds inhabit the Indian Ocean, Red Sea, and warmer latitudes of the Pacific; 49 belong to the Mediterranean and eastern side of the North Atlantic, and 118 have been detected on the American side of that sea. The North American fauna embraces one-ninth of the species composing the family, all, with the slight exceptions we shall mention, peculiar to that country, not one of them ranging to Europe. The exceptions are *holocentrum longipinne*, which goes as far north on the American side as Carolina, but crosses the Atlantic within the tropics to Ascension and St. Helena; and *trichodon Stelleri*, which is found both on the Asiatic and American shores of the sea of Kamtschatka. The last-named fish is the most northerly of the known American *percoideæ;* and the *lucioperca Americana*, which inhabits fresh waters up to the 58th parallel, stands next to it in that respect. The *perca vulgaris* being an inhabitant of the Siberian rivers, which fall into the Icy sea, is one of the most northerly of the family, though the very nearly allied American species have not hitherto been detected in a higher latitude than the 45th. With respect to the *distribution of generic forms*, Europe nourishes nine, which are not known to exist in North America, viz. *lates, apogon, pomatomus, aspro, acerina, polyprion, trachinus, sphyræna*, and *paralepis;* and North America ten, which are not found in Europe, viz. *huro, centropristes, grystes, centrarchus, pomotis, bryttus, aphrodederus, trichodon, holocentrum*, and *polynemus*, besides the doubtful genera proposed by M. Rafinesque: only five are common to the two faunæ, viz. *perca, labrax, lucioperca, serranus* and *uranoscopus*. *Grystes*, containing only two described species, forms another link connecting the American and Australian faunæ; one of the species

inhabiting the rivers of Carolina, and the other those of New South Wales. There is a greater variety of forms, as well as a greater number of species of fresh water percoideæ in North America than in any other quarter of the globe; indeed no other quarter possesses such an extent of fresh waters.

Cottoideæ.—This being a more northern family than the preceding one, we find, as in the higher orders of animals, a greater proportion of its generic forms common to the New and Old World;—the condition of the waters as well as of the land and atmosphere of the arctic regions of the two hemispheres is more alike than in the more temperate parallels. *Prionotus* and *hemitripterus* are the only two cottoid genera which frequent the Atlantic coasts of America, and do not also occur in Europe. On the north-west coast, however, there are three genera which are unknown in the European seas, viz. *hemilepidotus*, *blepsias*, and *temnistia*. The Mediterranean produces *peristedion* and *hoplostethus*, of which no species has been detected on the American coast. Five genera are common to both sides of the North Atlantic, as are also several species, viz. *trigla pini*, *dactylopterus volitans*, *aspidophorus europæus*, *scorpæna porcus*, and *sebastes norvegicus*, all marine fish; there are moreover some fresh water *cotti* and *gasterostei* in America, which are with great difficulty distinguishable from their European representatives. The family contains in all about 170 species, of which one-fifth are North American, and between one-fifth and one-sixth European.

Sciænoideæ.—The fish of this family, more closely related to the *percoideæ* by external form than the preceding, are also intimately connected with them by internal structure. The *sciænoideæ* are more American than either of the preceding families, one-third of the genera being proper to the Atlantic coast of that continent, and several of the remaining genera being represented there by one or more species. There are also four or five times as many species in the North American seas as in Europe; while the intertropical seas nourish four-fifths of the whole family. None are common to both sides of the Atlantic. Several of the American *sciænoideæ* make a remarkable grunting noise in the water, which is thought by Cuvier to be connected with the cavernous recesses in the skulls of fish of this family. The noise made by several of the *cottoideæ* when handled is evidently produced by the sudden escape of a quantity of air from their distended branchial membranes. The total number of ascertained species of the family is about 260.

Sparoideæ.—This family, of which 150 species are known,

has few representatives in North America, their number not exceeding one-thirtieth of the whole, while the European seas nourish nearly one-fifth; the majority of the species, as in most other acanthopterygian families, belong to the Indian and South Seas.

Mænoideæ.—Of this very small family, comprising only 42 species, about one half belong to the Indian and Polynesian seas, one fourth frequent the seas of Europe, and only one species, *gerres aprion*, has been detected on the shores of Carolina, to which it ranges from between the tropics.

Chætodontoideæ.—This family, named also *squammipennæ*, contains about 150 species, of which the greater part are inhabitants of the Indian and Polynesian seas. One species only (*brama Raii*) frequents the European coasts, while four are North American, and one seventh of the whole exist on the Atlantic coasts of North and South America. The *pempheris mexicanus* is found at Acapulco; the remaining species of that genus inhabit the tropical, Pacific, and Indian oceans.

The next family in Cuvier's arrangement is that of the *anabasideæ* or *polyacanthoideæ*, containing only 40 species, all of which belong to Southern Asia, except a *spirobranchus*, which inhabits the rivers of the Cape of Good Hope.

The preceding acanthopterygian families, with the addition of the *fistularoideæ*, hereafter mentioned, and the *platessoideæ*, anged by Cuvier with the *malacopterygii*, constitute Agassiz's order CTENOIDEI, so named from the pectinated laminæ of their scales. About 1400 recent ctenoideans have been described.

Scomberoideæ.—This family, included by Agassiz in his order CYCLOIDEI, is, next to the *percoideæ*, the most numerous of Cuvier's *acanthopterygii*, the described species amounting to more than 320. The *scomberoideæ*, more than any other group of fish of equal magnitude, affect the surface of the ocean especially in the warm latitudes, and a considerable number of the species roam from one side of the Atlantic to the other, among which are the *scomber grex*, *pelamys sarda*, *trichiurus lepturus*, *elecate atlantica*, *lichia glauca*, *caranx carangus*, and *nomeus Mauritii*. Of sixteen genera, actually ascertained to be North American, only seven enter the European fauna, viz., *scomber*, *pelamys*, *naucrates*, *caranx*, *seriola*, *temnodon*, and *coryphæna*; but five of the remainder occur also on the African shores of the Atlantic, viz., *cybium*, *trichiurus*, *elecate*, *trachinotus*, *temnodon*, and *vomer*, leaving only two of the North American genera peculiar to the western side of the Atlantic, viz., *argyryosus* and *rhombus*. The forms peculiar to

Europe are, *lepidopus*, *astrodermus*, *luvarus*, *seserinus*, and perhaps *lampris*; while its seas nourish also *thynnus*, *auxis*, *xiphias*, *tetrapturus*, *lichia*, *mastacemblus*, *scyris*, *gallichthys*, *lampugus*, *centrolophus*, *stromateus*, and *zeus*, common to other seas, and some of these to tropical America. Two or three of these are enumerated by Dr. Smith in his list of Massachusetts fish; but as he has not given any details by which we can judge of the correctness of his nomenclature, they are put in italics in the foregoing table. *Scomber grex* and *temnodon saltator* have a most extensive range from the Cape of Good Hope across the Atlantic to the coasts of the United States. The latter is also known eastward to Madagascar and along the whole western coast of Africa to the Mediterranean and Egypt, while the former is scarcely distinguishable from the Mediterranean *scomber pneumatophorus*. There are several of the *scomberoideæ* which, inhabiting only the middle longitudes of the Atlantic, belong as much to the New as to the Old World: they pursue the flying-fish over the Atlantic wastes as the herds of wolves do the bison on the prairies of America.

Acanthuroideæ.—Of this family about ninety species are known, inhabiting the warmer districts of the ocean and feeding on fuci, being furnished with cutting-teeth instead of prehensile ones, like those of most other fish. Except three species which frequent the Caribbean Sea, the family belongs to the Polynesian and Indian oceans and the Red Sea; one species follows the gulf-stream to New York, another reaches the Bahamas: none visit Europe.

Atherina.—This isolated genus contains about thirty species, of which six or seven are European, and five, exclusive of two or three doubtful ones, have been described as North American, but none are common to both sides of the Atlantic.

Mugiloideæ.—Of four generic forms which belong to this family, three are peculiar to the intertropical seas, while the typical one, *mugil*, is known in all the temperate as well as in the warmer districts of the ocean. None of the species cross the Atlantic, but some of them have a considerable range coastways; thus, two of the American mullets extend from the Brazils to New York, while the *mugil capito* ranges from Norway to the Mediterranean. The genus contains fifty-three described species, the whole family about sixty; several are confined to fresh waters.

Gobioides.—This family contains nearly 300 species, of which about one half are inhabitants of the Indian and Polynesian seas; sixty exist in the European waters, and eighteen or nineteen on the American side of the northern Atlantic,

there being only forty-two known on the whole eastern coast of both North and South America. The North American and European genera are mostly the same; yet among the former we have *chasmodes* and *philyprinus* which range from within the tropics to the United States, but do not visit Europe; while *tripterygion* and *callionymus* of the Mediterranean and British Channel are unknown in the American seas. The only species perhaps common to both countries are those which frequent the Greenland seas. Dr. Smith, indeed, enumerates *anarrhichas lupus* among the fish of Massachusetts, but his determination of the species must be considered as doubtful until we have some evidence of a proper comparison having been instituted between American and European examples. The *gunnellus vulgaris* is also described as a Labrador fish in the *Fauna Boreali-Americana*, on the authority of a single injured specimen which differed slightly from the English fish. *Zoarces polaris*, according to Capt. James Ross, is the most northern known fish, having been taken on the ice to the north of Spitzbergen, or within nine degrees of the pole; it ranges westward to Regent's Inlet.

Batrachoideæ.—The only species of this family which exists in Europe is the well known *lophius piscatorius*, while the North American seas contain four out of five of the generic forms and seven or more species, there being about fifty in the family. Sixteen belong to the Caribbean Sea and South American Atlantic, and the comparatively small proportion of fifteen have been detected in the Indian and Polynesian seas.

Labroideæ.—As the publication of the *Histoire des Poissons*, the only trustworthy guide for general ichthyology, has advanced no further than the *batrachoideæ*, our observations on the succeeding families must necessarily be imperfect, and we shall therefore make them as brief as possible; indeed, our American lists cannot be otherwise than very defective, being founded on Cuvier's notes in the *Règne Animal*, relating almost solely to figured species. We have ventured to enumerate only thirteen *labroideæ* as inhabitants of the North American seas, and the nomenclature of fully one half of these is doubtful. The European seas nourish about fifty species belonging to the genera *labrus, julis, crenilabrus, coricus, xirichthys, chromis*, and *scarus*.

Fistularoideæ.—The members of this small family are mostly denizens of the warmer seas. One species only is well known as European, viz., the *centriscus scolopax*, which is common enough in the Mediterranean, but rare in the Atlantic, though it has been found as far north as Mount's Bay. This family

closes the list of Cuvier's acanthopterygian fishes. The total number of described species belonging to the order amounts nearly to 2400.

Ord. MALACOPTERYGII ABDOMINALES.

Fam. CYPRINOIDEÆ.

Barbus, spec. novæ, Cuv. *Reg. An.*
Abramis balteatus, *F.B.A.* 3. 301. *Columb. R.*
„ *Smithii,* Id. 3. 110. *St. Lawrence.*
„ *chrysopterus,* Smith, *Massach.*
Labeo cyprinus, Le Sueur, *Ac. Sc. Ph.*
„ maxilingua, Id. *l. c. Maryland.*
„ *? macropterus,* Raf. *Ac. Sc. Ph.* 1.
„ *? annulatus,* Id. *l. c.* 17. 4. *N. York.*
„ *? nigrescens,* Id. *l. c. L. Champl.*
Catastomus gibbosus, Le Sueur, *l. c. Connect. R.*
„ tuberculatus, Id. *l. c. Penns.*
„ macrolepidotus, Id. *Delaware R.*
„ aureolus, Id. *L. Erie.*
„ communis, Id. *Delaware R.*
„ longirostris, Id. *Vermont.*
„ nigricans, Id. *L. Erie.*
„ maculosus, Id. *Maryland.*
„ elongatus, Id. *Ohio.*
„ vittatus, Id. *Penns.*
„ Dusquesnii, Id. *Ohio.*
„ Bostoniensis, Id. *N. Engl.*
„ oblongus, Id. *N. York.*
„ sucetta, Id. *S. Carol.*
„ teres, Lacep. v. 15. 2. *N. York.*
„ Hudsonius, Forst. *Ph. Tr.* 63. 6. *F.B.A* 46° N.—68° N.
„ Forsterianus, *F.B.A.* Back's *Voy. fig.* 48° N.—68° N.
„ reticulatus, Id. Back's *Voy. fig.* 40° N.—50° N.
„ *anisurus,* Raf. *Ohio.*
„ *anisopterus,* Id. *do.*
„ *bubalus,* Id. *do.*
„ *niger,* Id. *do.*
„ *carpio,* Id. *do.*
„ *velifer,* Id. *do.*
„ *xanthopus,* Id. *do.*
„ *melanops,* Id. *do.*
„ *melanotus,* Id. *do.*
„ *fasciolaris,* Id. *do.*
„ *erythrurus,* Id. *do.*
„ *flexuosus,* Id. *do.*
„ *megastomus,* Id. *do.*
Cycleptes nigrescens, Raf. *Ohio.*
Leuciscus gracilis, *F.B.A.* 78. *Saskat. R.*
„ chrysoleucus, Mitch. 40° N.—46° N.
„ caurinus, *F.B.A.* 3. 304. *Columb.*
„ oregonensis, Id. 3. 305. *do.*
„ *species novæ,* Cuv. *Reg. An.*
„ *atronasus,* Mitch. *N. York. Mass.*
Semotilus dorsalis, Raf. *Ohio.*
„ *cephalus,* Id. *do.*
„ *diplemia,* Id. *do.*
„ *notatus,* Id. *do.*
Minnilus dinemus, Id. *do.*
„ *notatus,* Id. *do.*
„ *microstomus,* Id. *do.*
Luxilus erythrogaster, Id. *do.*
„ *chrysocephalus,* Id. *do.*
„ *Kentuckiensis,* Id. *do.*
„ *interruptus,* Id. *do.*
Rutilus plargyrus, Id. *do.*
„ *compressus,* Id. *do.*
„ *amblops,* Id. *do.*
„ *melanurus,* Id. *do.*
„ *anomalus,* Id. *do.*
„ *ruber,* Id. *do.*
Pimephales promelas, Id. *do.*
Hypentelium macropterum, Id. *do.*
Hydrargyra diaphana, Le Sueur, *Ac. Sc. Ph. Saratoga lake.*
„ *multifasciata,* Id. *l. c. do.*
„ *ornata,* Id. *l. c. Delaware R.*
„ *nigrofasciata,* Id. *l. c. Rhode Is.*
Pœcilia multilineata, Le Sueur, *l. c. Florida.*
„ Schneideri, Valenc. *Obs. Zool.*
Lebias ellipsoidea, Le Sueur, *l. c. Arkansas R.*
Fundulus fasciatus, Valenc. *l. c. N. York.*
„ cœnicolus, Id. *l. c. N. York.*
Molinesia latipinna, Le Sueur, *l. c. N. Orleans.*
Cyprinodon flavulus, Valenc. *l. c. N. York.*
„ ovinus, Mitch. *N. York.*

Fam. Esocidæ.

Esox lucius*, *L.* 38° N.—68° N. East of Rocky M. only.
„ estor, Le Sueur, *Ac. Sc. Ph. L. Erie & Huron.*
„ reticulatus, Id. *l. c. Connect. R.*
„ phaleratus, Id. *l. c. Florida.*
„ niger, Id. *l. c. L. Saratoga.*
„ *vittatus*, Raf. *Ohio.*
„ *salmoneus*, Id. *do.*
Belone —? Smith, *Massach.*
Scomberesox equirostris, Le Sueur, *Massach.*
Scomberesox scutellatus, Le Sueur, *Newfoundland.*
Sarchirus vittatus, Raf. *Ohio.*
„ *argenteus*, Id. *do.*
Exocœtus exiliens, Bl. 397. *Trop. seas.—N Y. & Pacif.*
„ furcatus, Mitch. *G. of Mex.—N. York.*
„ comatus, Id. *N. York.*
„ mesogaster, Id. *do.—Massach.* Smith.
„ volitans, Bl. 398. *Trop. seas, Atl. & Pacif.*—30° N.

Fam. Siluroideæ.

Bagrus marinus, Mitch. *N. York.*
„ ? *hornpout*, Smith, *Massach.*—?
„ —? Benn. *Mazatl. Pacif.*
Pimelodus catus, Cat. 2, 23. *U. S.*
„ albidus, Le Sueur, *Mem. Mus. U. S.*
„ nebulosus, Id. *l. c. do.*
„ æneus, Id. *l. c. do.*
„ cauda furcata, Id. *l. c. do.*
„ nigricans, Id. *L. Erie.*
„ natalis, Id. *U. S.*
„ insigne, Id. *U. S.*
„ cænosus, *F.B.A.* 3, 122. *L. Huron.*
„ *borealis*, Id. *Saskatch. R.*
„ *maculatus*, Raf. *Ohio.*
Pimelodus cærulescens, Raf. *Ohio.*
„ *pallidus*, Id. *do.*
„ *argyrus*, Id. *do.*
„ *viscosus*, Id. *do.*
„ *nebulosus*, Id. *do.*
„ *cupreus*, Id. *do.*
„ *lividus*, Id. *do.*
„ *melas*, Id. *do.*
„ *xanthocephalus*, Id. *do.*
„ *limosus*, Id. *do.*
Pylodictis limosus, Id. *do.*
Noturus flavus, Id. *do.*
Doras costatus, Cat. *Sup.* 9. *U. S.*
Callichthys —? Bl. 397, 1. *do.*
Aspredo lævis, Seba, 29, 9, 10. *do.*

Fam. Salmonoideæ.

Salmo salar*, *F.B.A. Connect. R.* to *Labr.*
„ Scouleri, Id. 93. *New Caled.*
„ Rossii, Id. 80, 85, 2. *Arct. sea.*
„ *Hearnii*, Id. *do.*
„ alipes, Id. 81, 86, 1. *do.*
„ nitidus, Id. 82, 1. 86, 2. 52° N.—72° N.
„ Hoodii, Id. 82, 2. 83, 2. 87, 1. 52° N.—72° N.
„ fontinalis, Id. 82, 1. 87, 2. *N. York.—L. Huron.*
„ namaycush, Id. 79, 85, 1. 44° N.—68° N.
„ *quinnat*, Id. *Columb. R.*
„ *Gairdneri*, Id. *do.*
„ *paucidens*, Id. *do.*
„ *tsuppitch*, Id. *do.*
„ *Clarkii*, Id. *do.*
„ *carpio*, Fabr. *Greenl.*
„ *alpinus*, Id. *do.*
„ *stagnalis*, Id. *do.*
„ *rivalis*, Id. *do.*
„ *alleghaniensis*, Raf. *Ohio.*
Salmo nigrescens, Raf. *Ohio.*
Stenodus Mackenzii, *F.B.A.* 84, 94, 1. Back's *voy. Mack. R.*
*Osmerus eperlanus**, Arted. *Massach.—St. Lawr.*
Mallotus villosus, Cuv. *Arct. S.—Newf. & Kamtsch.*
„ pacificus, *F.B.A. Columb. R.*
Coregonus albus, Id. 89, 2. 94, 2. 44° N.—72° N.
„ tullibee, Id. 50° N.—54° N.
„ Artedi, Le Sueur, *Ac. Sc. Ph. L. Erie.*
„ lucidus, *F.B.A.* 90, 1. *Gr. Bear L.*
„ harengus, Id. 90, 2. *L. Huron.*
„ quadrilateralis, Id. 89, 1. 60° N.—72° N.
„ labradoricus, Id. *G. of St. Lawrence.*
Thymallus signifer, *F.B.A.* 88. 62° N.—68° N.
„ *thymalloides*, Id. *lat.* 64½° N.
Saurus mexicanus, Cuv. *L. of Mex.*

Fam. CLUPEOIDEÆ.

Clupea *harengus**, AUCT. 40° N.—75° N. *Pacif. Atl. & Arct. Seas.*
„ *humeralis*, CUV. *G. of Mex.*
„ fasciata, LE SUEUR, *Ac. Sc. Ph. Penns.*
„ elongata, ID. *Marble head.*
„ *halec*, MITCH. *N. York.*
„ *pusilla*, ID. *do.*
„ *parvula*, ID. *do.*
„ *indigena*, ID. *do.*
„ *vittata*, ID. *do.*
„ *cærulea*, ID. *do.*
Alosa vernalis, MITCH. v. 9. *N. York, Mass.*
„ æstivalis, ID. *N. York.*
„ menhaden, ID. v. 7. *do. Massach.*
„ matowaka, ID. v. 8. *do.*
„ *alosa**, ID. *N. York. Mass.*
„ *mediocris*, ID. *do.*
„ *minima*, SMITH, *Massach.*
Pomolobus chrysochloris, RAF. *Ohio.*
Dorosoma notata, RAF. *Ohio.*
Notemigonus auratus, ID. *do.*

Chatoëssus oglina, LE SUEUR, *Ac. Sc. Ph. Rhode Is.*
„ Cepedianus, ID. *l. c. Pennsylv.*
„ *thrissa*, CUV. *G. of Mex.*
„ *notata*, ID. *do.*
Engraulis sadina, MITCH. *N. York.*
„ *encrasicholus**, BL. 302. *Greenl.* FABR.
„ *edentulus*, CUV. *G. of Mex.*
Elops saurus, LACEP. v. 398. *W. Ind.—Carol. Calif.* BENN.
Butirinus vulpes, CAT. 1, 2. *Braz.—U. S.*
Hiodon tergisus, LE SUEUR, *l. c. L. Erie. Ohio.*
„ clodalis, ID. *Ohio.*
„ *chrysopsis*, *F.B.A.* 91, 3. 52° N.—54° N.
„ *vernalis*, RAF. *do.*
„ *heterurus*, ID. *do.*
„ *alosoides*, ID. *do.*
Amia calva, BL. SCHN. 80. *Carol.*
„ *ocellicauda*, *F.B.A. L. Huron.*

Fam. SAUROIDEÆ. (Agassiz.)

Lepisosteus osseus, L. *U. S.*
„ huronensis, *F.B.A. L. Huron.*
„ gracilis, AGASS. *Zool. Pr.*
„ *longirostris*, RAF. *Ohio.*
„ *oxyurus*, ID. *do.*
Lepisosteus albus, RAF. *Ohio.*
„ *platostomus*, ID. *do.*
„ *ferox*, ID. *do.*
„ spatula, LACEP. 5, 6, 2. *Ohio.*
Litholepis adamantinus, ? RAF. *Ohio.*

The second division of the fish, according to Cuvier's arrangement, or the MALACOPTERYGII, includes the bulk of Agassiz's CYCLOIDEI, together with some families belonging to the other orders of the latter naturalist, as the *siluroidei* and *sauroidei* which rank with his GANOIDEI, and the *platessoideæ* or *pleuronectoideæ* which he places among his CTENOIDEÆ: on the other hand, we have already noticed that Agassiz's CTENOIDEÆ include the *scomberoideæ, atherinæ, mugiloideæ,* and *labroideæ,* considered by Cuvier as Acanthopterygians.

The MALACOPTERYGII ABDOMINALES embrace the greater part of the fresh water fish, and though few species are common to Europe and North America, there is much similarity between the generic forms existing in the waters of the two continents. As the lakes and rivers, however, occupy more space in proportion to the land in North America than in any other quarter of the world, so the number and variety of fresh water fish is greater than in Europe, or any other extra-tropical country.

Cyprinoideæ.—Europe nourishes 32 species of this family: it possesses, in common with America, the forms of *barbus*, *abramis*, and *leuciscus*; *labeo*, existing in the Nile, is also American; *cyprinus*, *gobio*, *tinca*, and *cobitis*, which are European, have not yet been proved to exist on the other side of the Atlantic: while North America possesses *catastomus*, *hydrargyra*, *pœcilia*, *lebias*, *fundulus*, *molinesia* and *cyprinodon*, unknown to European waters, besides the uncertain genera proposed by M. Rafinesque.

Esocidæ.—The fresh waters of America contain a greater number of species of this family than those of Europe, the only one in fact in the latter country being the common pike or *esox lucius*, which exists also abundantly in North America, though it is confined to the eastern side of the Rocky Mountains. North Africa is more productive, the Nile producing many *mormyri*, and the Mediterranean yielding a single species each of *alocephalus*, *microstoma*, *stomias*, and *chauliodus*, forms which have not been detected on the western side of the Atlantic. *Belone*, *scomberesox* and *exocœtus*, are common to both sides of that sea, and it is highly probable that some of the *hemiramphi* of the Caribbean sea may follow the gulf stream further north: one was taken this year on the coast of Cornwall*.

Siluroideæ.—Though a considerable number of fish of this family have been already discovered in North America only one is known in Europe, viz., the *silurus glanis*, which inhabits the rivers of Europe as far north as Sweden and Norway, as well as those of Asia and North Africa. The *pimelodus borealis*, the most northerly of the family in America, goes no higher than the 54th parallel. The waters of Egypt nourish many species of *silurus*, *schilbus*, *bagrus*, *pimelodus*, *synodontis*, *clarias*, and *malapterurus*.

Salmonoideæ.—Upwards of thirty described species of this family belong to Europe, which possesses all the generic forms mentioned in our North American list, with the exception of *stenodus*†, and the addition of *argentina* and *scopelus*, found in the Mediterranean. Egypt produces two or three other forms, one of them, *myletes*, being common also to tropical America. Some of the *salmonoideæ* are the most northerly of fresh water fish. Several of the trouts of North-west America are probably identical with Kamtschatka species, to which other names had been previously given. This point, with many others, will

* Yarrell, *Br. Fishes*, p. 397.

† This genus or sub-genus, which differs from the other *salmones* in the teeth, was first named in the Appendix to Captain Back's narrative of his journey to he mouth of the Thleweechoh.

doubtless be cleared up in the ensuing volumes of the *Histoire des Poissons.* The identity of the *salmo salar* itself on both sides of the Atlantic has not been satisfactorily settled, and some interesting facts in the history of the fish as an inhabitant of Lake Ontario require to be ascertained ; for instance, whether it descends to the sea after spawning, or whether, like the salmon of Lakes Wenern and Wettern, in Sweden, it passes its whole life in fresh water†, recruiting in the depths of the lake, and spawning in the feeding streams. The truth of the report, that none of the salmon which ascend the Columbia, or the rivers of New Caledonia, return again to the sea, deserves to be inquired into :—the same thing has been asserted of the salmon of Northern Asia.

Clupeoideæ.—This family is also more numerous in North America than in Europe, the latter country yielding only nine or ten species belonging to the genera *clupea, alosa,* and *engraulis. Hiodon,* a genus peculiar to America, has much affinity to the *salmonoideæ.*

Sauroideæ.—This family contains only two existing genera, *lepisosteus,* peculiar to America, and *polypterus* to Africa‡.

Ord. MALACOPTERYGII SUB-BRACHIALES.

Fam. GADOIDEÆ.

Gadus morrhua*, L. *Polar s. Newf. N. York. S. of Kamtsch.*
„ *callarias**, L. *N. York,* MITCH. *Greenl.* FABR.
„ *rupestris,* SMITH, *N. York. Massach.*
„ *arenosus,* ID. *do. do.*
„ *tomcodus,* MITCH. *do. do.* SMITH.
„ *æglefinus,* PENN. *do.* MITCH.
„ *fasciatus,* ID. *do.* MITCH. *Massach.* SM.
„ *blennoides,* MITCH. *do.*
„ *barbatus**, BL. 166. *Massach.* SM.
„ *Fabricii, F.B.A. Greenl.* FABR.
„ *ogac,* ID. *Greenl.* FABR.
„ *luscus**, PENN. *S. of Kamtsch.* TILES.
„ macrocephalus, TILES. *M. Petr.* 2, 16. *S. of Kamts.*
„ gracilis, ID. 18. *do.*
Merlangus carbonarius*, BL. 66. *Davis' S. Pacif.*
Merlangus polaris, SABINE, *Parry's App. Polar s. Spitz.*
„ *vulgaris**, SMITH, *Massach.*
„ *albidus,* MITCH. *N. York.*
„ *purpureus,* ID. *do.*
„ *pollachius**, SMITH, *Massach.*
Merluccius asellus*, BL. 164. *N. York.—Newf.*
Lota maculosa, LE SUEUR, *Ac. Sc. Ph. L. Erie.*—68° N.
„ compressa, ID. *l. c. Connect. R.*
Brosmius flavescens, ID. *M. Mus.* 5, 16.2. *Newf.*
„ *vulgaris**, PENN. *Massach.* SMITH.
„ *lub**, *Mem. Stockh.* 15,8. *Greenl.*
Phycis chuss, SCHŒPF. *N. York.*
„ *tenuis,* MITCH. *N. York.*
„ *punctatus,* ID. *F.B.A.* 3, 253. *N. York, Nova Scotia.*
Raniceps blennoides, SMITH, *Massach.*
Macrourus rupestris*, BL. 26. *Greenl. North s.*

† NILSSON, *Pisces Scand.*

‡ The GANOIDEI of Agassiz are composed of the *sauroideæ, lepidoideæ* (fossil), *pycnodontes, plectognathi, lophobranchii, goniodontes, siluroideæ,* and *sturionideæ.*

Fam. PLEURONECTOIDEÆ.

Platessa plana, MITCH. *N. York.*
,, stellata, PALL. *Polar s. S. of Kamtsch.*
,, *dentata*, L. *N. York*, SCHŒPF.
,, *americana*, SCHŒPF. *Rhode Is.*
,, *melanogaster*, MITCH. *N. York.*
,, *oblonga*, ID. *do.*
*Hippoglossus communis**, BL. 47. *N. York. Mass.* SM. *Pacif.* ESCHSCHOLTZ.
Rhombus argus, CAT. 27. *Bahamas. U.St.*
,, *glacialis*, PALL. *Awatska. Polar s.*
,, *maximus**, SMITH, *Massach.*
,, *aquosus*, MITCH. *N. York.*
*Solea vulgaris**, PENN. *Massach.* SMITH.
Achirus lineatus, SLOANE, 346, *Carib. s. N. York.* MITCH.
,, plagiurus, L. *Carib. s.—Carol.*

Fam. DISCOBOLI.

*Cyclopterus lumpus**, BL. 90. *N. York.—Greenl. Eur.*
,, *minutus*, PALL. *Mass.* SMITH.—*Greenl.* ROSS.
Cyclopterus spinosus, FABR. *Greenl.*
,, *ventricosus*, PALL. *S. of Kamtsch.*
*Liparis communis**, ARTEDI, *Eur. Polar s.*
,, *gelatinosus*, PALL. *S. of Kamtsch.*

Fam. ECHENEIDEÆ.

Echeneis remora*, BL. 172. *N. York. Mass. Pacif.*
,, naucrates*, ID. 171. *Massach. Newf. Pacif.*
Echeneis species aliæ, U. S. Pacif. BENN.

MALACOPTERYGII SUB-BRACHIALES.—Most of the fish of this order feed on or near the bottom, and a very considerable number of the species are common to both sides of the Atlantic, particularly in the higher latitudes, where they abound. It does not appear that their general diffusion ought to be attributed to migration from their native haunts, but rather that in this respect they are analogous to the owls, which, though mostly stationary birds, yet include a greater proportion of species common to the Old and New Worlds than even the most migratory families. Several of the *scomberoideæ* which feed on the surface have been previously noted as traversing many degrees of longitude in the Atlantic, but the existence of the ground-feeding *gadoideæ* in very distant localities must be attributed to a different cause, as it is not probable that any of them wander out of soundings, or ever approach the mid-seas.

Gadoideæ.—About twenty-one species of this family frequent the European seas, most of which, and all the generic forms, have been enumerated by authors as existing also on the North American coast. More exact comparisons will probably diminish the number of species supposed to be common to the two countries, but still a sufficient number will remain to justify the preceding remarks.

Pleuronectoideæ.—Upwards of thirty-six species of flat-fish belong to Europe, two or three of which, and all the generic forms, except *monochir*, occur in the lists of American ichthyo-

logists. Many more will doubtless be detected hereafter on the coasts of Nova Scotia, Newfoundland, and Labrador.

Discoboli.—About eight species of this family, belonging to the genera *lepadogaster, gobiesox, cyclopterus,* and *liparis* have been described as European. The American *discoboli* are almost entirely unknown.

Echeneideæ.—The singular fish belonging to this family, though they swim rapidly for a short time, do not appear capable of long-continued exertion. The necessity for this is indeed obviated by the adhesive apparatus on the head, by which they can attach themselves to the larger fishes, and especially to the sharks. In this way they are carried about, and are always at hand to feed on any morsels that may be detached when the monster closes his saw-like teeth on his prey. They also stick to the bottoms of ships, being attracted by the greasy washings of the coppers thrown overboard by the cook, and thus they are often carried beyond the warmer seas in which they are produced. The two species which are best known have been taken on both sides of the Atlantic, as well as in the Pacific. They range occasionally northwards to England and the banks of Newfoundland.

Ord. MALACOPTERYGII APODES.

Fam. ANGUILLIFORMES.

Muræna rostrata, LE SUEUR, *L. Cayuga* and *Seneka.*
„ bostoniensis, ID. *Massach.*
„ serpentina, ID. *Long. Is.*
„ argentea, ID. *Boston Bay.*
„ macrocephala, ID. *Saratoga.*
„ *vulgaris**, SMITH, *Mass. N. York.* MIT.
„ *conger**, MITCH. *Surinam, do. do.*
„ *oceanica*, ID. *N. York.*
„ *laticauda*, RAF. *Ohio.*
„ *aterrima*, ID. *do.*
Muræna xanthomelas, RAF. *Ohio.*
„ *lutea*, ID. *do.*
„ *helæna*, CAT. 20. *Bahamas.*
Murænophis moringa, CAT. 21. *do.*
„ *meleagris*, MITCH. *U. S.*
Saccopharynx ampullaceus, HARWOOD, *Ph. Tr. Davis' Straits.*
„ chordatus, MITCH. 52° *N. lat.*
Ammodytes lancea*, CUV. *Greenl.* FABR.
„ *tobianus**, PENN. *N. York. Newf.*
Ophidium *stigma*, BENN. *Kotzebue Sound.*

Anguilliformes.—From 25 to 30 species belonging to the single family forming this order have been detected in the European Seas. They are arranged by Cuvier in the genera *anguilla, conger, ophisurus, muræna, sphagebranchus, leptocephalus, ophidium* and *ammodytes.* The Nile supports another generic form named *gymnarchus.* One of the species of *saccopharynx* having been caught in mid-seas belongs as much to Europe as to America. The members of the family existing in the American waters are very imperfectly known.

Ord. LOPHOBRANCHII.

Sygnathus typhle, Bl. 91, 1. *N. York, Mass.* Mitch. Sm.	*Sygnathus acus*, Bl. 91, 2. *U. S.* Penn.
	Hippocampus brevirostris? N. York. Mitch.

Of this order, consisting, like the preceding one, of only one natural family, there are about 15 European species. The American naturalists have mentioned the same generic forms as existing in their seas, but no correct details of the species of the northern part of the New World have yet been published.

Ord. PLECTOGNATHI.

Fam. Gymnodontes.

Diodon punctatus, Bl. 125, 126. *Braz.—N. York.* Schœpf.	Tetraodon *hispidus*, Schœpf. *N. York.*
„ rivulatus, Cuv. *N. York.* Mitch. 6, 3.	„ turgidus, Mitch. 6, 5. *do. Massach.*
„ pilosus, Mitch. 6, 4. *N. York.*	„ lævigatus, Will. I. 2.
Tetraodon geometricus, Cat. 28. *Bah.—U. S.*	„ curvus, Mitch. *N. York.*
„ *lineatus*, Bl. 141. *New York.* Schœpf.	„ mathematicus, Id. *do.*
	„ lagocephalus, Cat. 28. *Virg.*
	Orthagoriscus mola, Bl. Schn. *U. S.*
	„ *brevis*, Mitch. *N. York.*

Fam. Sclerodermata.

Balistes tomentosus, L. Seba, 24, 18. *U. S.*	*Balistes aurantiacus*, Mitch. 6, 1. *New York.*
„ vetula, Bl. 150, Cat. 22. *Bahamas.—U.S.*	„ *broccus*, Id. *N. York.*
„ hispidus, L. Seba, 24, 2. *U. S.*	*Ostracion triqueter*, Bl. 130. *Mass.* Sm.
„ monoceros, Cat. 19. *Bah. Mass.* Smith.	„ *bicaudalis*, Smith. *Mass.*
„ sufflamen, Mitch. 6, 2. *N. York.*	„ quadricornis, Bl. 134. *U. S.*

Gymnodontes.—This family of *plectognathi* belongs chiefly to the warmer seas, and the species have not yet been satisfactorily discriminated, especially the American ones. The *tetraodon Pennanti*, Yarr., (termed by Pennant *lævigatus* and *lagocephalus*,) and *orthagoriscus mola* and *oblongus* extend northwards to the English coast. The *tetraodon lineatus* inhabits the Nile. This species, and several others which exist on the eastern side of the Atlantic, occur in the lists of American ichthyologists; but in the absence both of good descriptions and figures there is reason to fear that much error exists in their determinations.

Sclerodermata.—This family also abounds within the Tropics, haunting coral banks and other rocky places. Many frequent the shores of the Bahamas, the Florida Keys and the Bermudas, but the species have not been fully described. The *balistes capriscus* of the Mediterranean and British Channel is the only European one.

Ord. CHONDROPTERYGII ELEUTHEROPOMI.

Fam. STURIONIDEÆ.

Acipenser transmontanus, *F.B.A.* 97. *f.* 2. *Columb. R.*
„ rupertianus, *F.B.A.* 97, 1. *Saskatch. R.*—50° N.—55° N.
„ brevirostris, LE SUEUR, *Am. Phil. Tr.* N.S. *Delaware R.*
„ maculosus, ID. *Ohio.*
„ oxyrhynchus, MITCH. *Delaw. N. York.*

Acipenser rubicundus, LE SUEUR, *l. c.* 12. *Canada lakes.*
„ *platyrhynchus*, RAF. *Ohio.*
„ *serotinus*, ID. *Ohio.*
„ *ohiensis*, ID. *Ohio.*
„ *macrostomus*, ID. *Ohio.*
Platirostra edentula, LE SUEUR. *Ohio.*
Polyodon folium, LAC. 13, 3. *Ohio, Mississ.*

Fam. CHIMÆROIDEÆ.

Chimæra Collæi, BANN. *N. Pacif.*

Elephant fish, VANCOUVER. *Straits of Da Fuca.*

Sturionideæ.—The western European waters produce only one species of this family, but several exist abundantly in the Danube and other rivers flowing into the Black Sea, and also in the rivers of Northern Asia. The species are still more numerous and various in North America and the Mississippi, and its tributaries nourish some curious forms found nowhere else. We are chiefly indebted to M. Le Sueur for our knowledge of the sturgeons of the United States, but a monograph of the family is much needed, the species both of the Old and New Worlds are as yet but badly determined.

Chimæroideæ.—Only two species of this family have been figured, viz., the *chimæra monstrosa*, an inhabitant of the North Atlantic, and the *callorhynchus antarcticus* frequenting the southern parts of the Atlantic and Pacific. On Captain Beechey's voyage at least two others were discovered, one on the coast of Chili, and another, named by Mr. Bennett *chimæra Colliæi*, in the Bay of Monterey. Vancouver took one in the Straits of Juan da Fuca, but he has given no description of it whatever whereby we may judge of the species.

Ord. CHONDROPTERYGII TREMATOPNEONTES,

(*Placoidei*, Agassiz.)

Fam. SELACHIIDEÆ.

Scyllium Edwardsii, CUV., EDW. 289.
„ *canis*, MITCH. *N. York.*
„ *canicula*, SMITH. *Mass.*
„ *catulus*, ID. *Mass.*
Carcharias obscurus, LE SUEUR, *Ac. Sc. Ph.* 9.

Carcharias littoralis, LE SUEUR, *N. York. Mass.*
„ terrænovæ, F. B. A. 3, 289. *Newf.*
„ *vulgaris*, BELON, 60. *N. York. Mass.* PENN. MIT. SM.
„ *vulpes*, SM. *Mass. N. York.*
„ *glaucus*, MITCH. *N. York. Mass.*

Carcharias punctatus, MITCH. *N. York.*
Selache maximus, ID. *N. York. Mass.*
„ *Americanus.* ID. *N. York.*
Somniosus brevipinna, LE SUEUR, *Ac. Sc. Ph. Mass.*
Zygæna malleus, VALEN. *Mass. N. York.*
„ tiburo, PENN. SM. *Mass.*
Squatina Dumerilii, LE SUEUR, *l. c.* 1, 10.
Pristis antiquorum, CUV. *U. S. Penn.*

Fam. RAIIDEÆ.

Torpedo sp.— BENN. *Monterey.*
„ — ? MITCH. *N. York.*
Raia Sayii, LE SUEUR, *N. Jersey.*
„ Desmarestii, ID. *Florida.*
„ eglanteria, ID. *Carolina.*
„ Chantenay, ID. *Pennsylv.*
„ *fullonica*, FABR. *Greenland.*
„ *ocellata*, MITCH. *N. York.*
„ *diaphana*, ID. *Do.*
„ *centroura*, ID. *Do.*
„ *bonasus*, ID. *N. York.*
Raia batis, SMITH. *Massach.*
„ *clavata*, ID. *Do.*
Trygon sabinum, CUV. *Florida.*
„ micrura, CUV. *N. Jersey.* LE SUEUR.
Myliobatis Fremenvillii, LE SUEUR. *Rhode Id.*
„ quadriloba, CUV. *N. Jersey.* LE SUEUR.
„ narinari, MARCGR. *San Blas.* BENN.
Cephaloptera mobular, DUH. 17. *Delaware.* LE SUEUR.
„ vampirus, MITCH., PENN. *N. York.*

Fam. CYCLOSTOMATA.

Petromyzon tridentatus, F. B. A. 3, 293. *Columb. R.*
„ *fluvialis*, ID. & MITCH. *N. York, Mack. R.*
Petromyzon marinus, MITCH. *N. York, Mass.*
„ *niger*, RAF. *Ohio.*

Selachiideæ.—The European seas nourish about thirty members of this family, belonging to the genera *scyllium, carcharias, lamna, galeus, mustelus, notidanus, selache, spinax, centrina, scymnus, zygæna, squatina*, and *pristis.* The sharks of the American seas have been very imperfectly investigated; but since the food provided for them is much the same as on the east side of the Atlantic, we may expect to find them exhibiting the same generic forms, and their analogy to the birds and beasts of prey would also lead us to the same conclusion.

Raiideæ.—Cuvier, in speaking of the Rays, observes that no confidence whatever can be reposed on the synonymy of Artedi, Linnæus, and Bloch, since these authors have taken their specific characters chiefly from the number of spines, which vary with the age and sex of the individual. Hence as the Linnæan names have been imposed on many of the American rays, our list is without doubt erroneous as well as defective. About twenty species have been described as inhabitants of the European seas; they are distributed by Cuvier into the following genera; *rhinobatis, torpedo, raia, trygon, myliobates*, and *cephaloptera.*

Cyclostomata.—Of this family, which contains the most simply organised fishes, the European seas nourish only about seven species belonging to the genera *petromyzon, gasterobranchus, ammocœtus*, and *amphioxus* (Yarrell), but there is reason to believe that the family is more numerous in the American waters. The *petromyzon tridentatus* which inhabits the estu-

ary of the Columbia, resembles *p. Planeri* in its fringed lips, and *fluviatilis* in the strength and form of its teeth, but not in their arrangement. Lampreys exist in the Mackenzie river which joins the Arctic sea in the 68th parallel.

The preceding report occupies a greater portion of the Society's valuable volume than I could have wished, but I was unable to compress it further without departing entirely from the plan that I have adopted. The list of species, though they might have been omitted had the paper referred only to a country like Europe, whose natural productions are fully enumerated in accessible treatises, are in fact essential to a view of the present state of our knowledge of the ferine inhabitants of a continent which confessedly nourishes many species still undescribed; and being moreover the *data* for our remarks on the geographical distribution of animal forms, they are necessary to enable the naturalist to judge of the value of the statements collected from the various authors referred to, and of the opinions offered upon them. The comparison between the *faunæ* of North America and Europe which runs throughout the paper, contributes to indicate not only the variations of animal life in different localities, and in different circumstances, under the same parallels of latitude, but also, though more obscurely and merely by analogy, the tribes of animals of which new species will be most probably hereafter detected in North America.

Zoology, as Cuvier has remarked, is now and must continue to be for many years, a science of observation only, and not of calculation; and no general principles hitherto established will enable us to say what are the aboriginal inhabitants of any quarter of the world. It seemed therefore hopeless to attempt to elicit the laws of the distribution of animal life from results yielded by a fauna so very imperfectly investigated as that of North America; consequently in the preceding report, the ranges of the species have been generally stated, as recorded by observers, and without any reference to the opinions which have been heretofore advanced by theoretical writers. Buffon hazarded the remark that none of the animals of the Old World exist in the New, except the few which are capable of propagating in the high northern latitudes. Temminck adduces circumstances which favour a modern opinion almost directly opposed to Buffon's; namely, that all the genera which people the earth (a small number belonging to the polar regions only excepted) are to be found in the equatorial zone, or at least within the tropics; and that the genera are spread abroad by means of analogues or species possessing exactly similar generic cha-

racters, which range in the same parallels of latitude, through all the degrees of longitude, and that notwithstanding the barrier which a wide ocean may be supposed to interpose*. The comprehensiveness of this law will evidently be modified by the number of generic divisions admitted by naturalists, and it will be scarcely tenable if the geographical groups of species be raised to generic rank as has been of late frequently done.

The report includes only the VERTEBRATA, but the fourth volume of the *Fauna Boreali-Americana*, by the Reverend William Kirby, now in the press, will give a complete review of the present state of North American ENTOMOLOGY. Almost all that is known of the CRUSTACEÆ, MOLLUSCÆ, and ZOOPHYTA of that country, is owing to the labours of Messrs. Say and Le Sueur, whose original papers are contained in the Journal of the Academy of Sciences of Philadelphia, so often quoted. Dr. S. G. Morton, in an able synopsis of the organic remains of the cretaceous group of the United States, lately republished from Silliman's Journal, gives the following list of recent shells common to the European and American coasts of the Atlantic.

Purpura lapillus.	Modiola papuana.
Buccinum undatum.	Mactra deaurata.
Natica carena.	Spirorbis nautuloides.
Fusus islandicus.	Thracia convexa.
Cyprina islandica.	Solecurtus fragilis.
Saxicava rugosa.	Glycimeris siliqua.
Lucina divaricata.	Cardium groenlandicum.
Pholas crispata.	" islandicum.
" costata.	Strigilla carnaria.
Solen ensis.	Tellina punicea.
Mya arenaria.	Pecten islandicus.
Mytilus edulis.	Balanus ovularis.

A list of the fresh-water shells of the fur countries occurs in the third volume of the *Fauna Boreali-Americana*.

EMENDANDA.

In page 168, line 9, for 85, read 75. The same error occurs in Audubon's Ornithological Biography, vol. i. p. 381.

Mr. Swainson's 2d vol. of the Natural History of Birds having been published while this paper was passing through the press, we followed it in making some changes in the arrangements of the *grallatores*, in consequence of which the following alterations require to be made in the columns of numbers of the table in page 177. *Tantalidæ* 5, 1, 1. *Ardeidæ*, 14, 14, 4. *Scolopacidæ*, 45, 37, 24. *Rallidæ*, 7, 7, 1. *Charadriadæ*, 8, 11, 3.

We have followed the common practice in arranging the phalaropes with the *scolopacidæ*; but they are, as Temminck has remarked, decidedly natatorial in their habits; and we may add, resemble the ducks in their under plumage and bills: on the other hand, the flamingo is, as Dr. Smith has observed, a true wader in its manners, and has been classed as such by all ornithologists except Mr. Swainson. *Vide* SWAINS. BIRDS, ii. p. 190.

* *Monogr.* &c.

Supplementary Report on the Mathematical Theory of Fluids. By the Rev. J. Challis, *Plumian Professor of Astronomy in the University of Cambridge.*

The object of the first Report which I read before the Association was to sketch out the processes of calculation, and exhibit the results obtained in the applications of analysis to fluids which were supposed either to be incompressible, and therefore of uniform density; or compressible in such a manner that the density is, under all circumstances, the same where the pressure is the same. Such fluids do not exist in Nature. All *liquids* are compressible in some degree, and the pressure in every aeriform fluid varies as well with the temperature as with the density; yet these hypothetical fluids are in a mathematical sense intimately allied to existing fluids. The results which calculation gives on the supposition of incompressibility admit of comparison with facts observed in the equilibrium and motion of *water;* and the laws of pressure, motion, and propagation of motion, arrived at in the mathematical treatment of the imaginary fluid, whose pressure is conceived to depend on the density alone, are first approximations towards a knowledge of what actually takes place in *air*. The comparison of the calculated results with fact and experiment, in these normal cases, serves to show the degree of influence to be attributed to the modifications which the fundamental properties of the imaginary fluids must undergo, to make them agree more nearly with those of real fluids. Of late years mathematicians have introduced such modifications into their theories, by reasoning from certain hypotheses, respecting the interior constitution of bodies, and the mechanical action of their molecules, for the purpose of treating mathematically of matter as it exists in Nature, and tracing to causes beyond the reach of direct observation and experiment the various sensible phænomena which it presents. I endeavoured in a second Report to give some account of the general principle of such theories, and to explain how they serve, by a satisfactory comparison of the theoretical results with experiments, to establish the truth of the hypotheses on which the mathematical reasoning is based, and so to make known, respecting the intimate constitution and unseen conditions of bodies, something which could not be ascertained by observation alone; as, in an instance in some respects analogous, mathematical calculations applied to electrical phænomena are considered to prove the existence of fluids whose

nature is such that they cannot be shown to exist by the evidence of the senses alone. The phænomena of capillary attraction appear to have principally led to hypotheses respecting the constitution and molecular action of liquids. The first writers on the subject considered it sufficient to treat the liquid as incompressible, and attribute to its molecules, and to those of the containing solids, an attracting force, sensible only at insensible distances from the attracting centres; on which supposition the problem does not materially differ from those that belong to the common theory of inelastic fluids. Poisson conceived it necessary to treat the question with more distinct reference to the molecular constitution of bodies, and to the repulsive, as well as attractive, forces which keep the molecules separate from each other in places of equilibrium. The views of this eminent mathematician respecting the constitution of fluid bodies, particularly as applied in his New Theory of Capillary Action, formed, together with an exposition of the theories of preceding writers, the main subject of my second Report. I propose, in the present essay, to speak of some other instances of the application of mathematics, in explanation of the phænomena of rest or motion of fluids, and carefully to distinguish, as heretofore, the calculations derived from hypotheses merely from those that set out from experimental facts. The mechanical theory of the atmosphere, and of the propagation of sound in it, as affected by the development of heat, will principally claim our attention. In conclusion, I shall take occasion to add some supplementary remarks on subjects contained in the preceding Reports, and to notice any additions that may have been very recently made to this department of science.

Mechanical Theory of the Atmosphere.—The pressure of a perfectly elastic fluid when at rest, and everywhere of the same temperature, varies in the same proportion as its density. This, the well-known law of Boyle and Mariotte, was recently proved to be true, for pressures amounting to twenty-seven times the mean atmospheric pressure, by a committee of the French Institute appointed for ascertaining the elastic force of steam, in some preliminary experiments for executing the purpose of the commission*. The modification this law must receive to take in the effects of change of temperature (the fluid still remaining at rest) was first stated by Dalton as a result of experiment, and confirmed very shortly after by the experiments of Gay-Lussac†.

* *Mémoires de l'Academie des Sciences*, tom. x. p. 207.

† The paper of Dalton was read before the Manchester Philosophical Society in October, 1801, and was published in 1802. Gay-Lussac's experiments appeared in the *Annales de Chimie*, 1802, tom. xliii. p. 137.

It was ascertained by the independent labours of these two eminent philosophers, that different aeriform bodies, submitted to the same constant pressure, receive equal increments of volume for the same increment of temperature; so that if the masses of any two be of equal size at one temperature, they will be of equal size at any other temperature, provided the pressure to which both are submitted, be the same and constant. It was also found by Gay-Lussac, that from the temperature of melting ice to that of boiling water, a mass of air, the size of which at the former temperature is expressed by unity, expands to a size expressed by 1·375. If the augmentation 0·375 be divided into 100 equal parts, and each of these parts be assumed to measure a degree of temperature, it will follow, from the theory enunciated above, that every gas dilates by the fractional part 0·00375 of its size at the temperature of melting ice for each degree of the centigrade air thermometer. Thus, v' being the volume when the temperature is $\theta°$ above zero, and v the volume when the temperature under the same pressure is at zero, the relation between the volume and temperature is expressed algebraically by the equation,

$$v' = v\,(1 + 0{\cdot}00375\,\theta).$$

Also if D', D be the densities corresponding to v', v, we have $D'\,v' = D\,v$, as the quantity of matter is constant. If now the pressure on a unit of surface be changed, without altering the temperature, from the constant value it has hitherto been supposed to have, which we will call ϖ, to the value p, the density at the same time changing from D' to ρ, the law of Mariotte gives $\frac{p}{\varpi} = \frac{\rho}{D'}$. These three equations easily conduct to the following relation between p, ρ, and θ;

$$p = \frac{\varpi\,\rho}{D} \cdot (1 + \alpha\,\theta),$$

where α is put for 0·00375. This formula is considered to apply to gases, to vapours, and to compounds of both, or either. The value of α is the same for all, but $\frac{\varpi}{D}$ differs for different fluids. If the unit of density for atmospheric air be assumed to be that at a particular place on the earth's surface at 0° centigrade, $\frac{\varpi}{D}$ will plainly be the pressure there at that temperature. MM. Biot and Arago found the ratio of the specific gravity of mercury to that of air at the temperature of melting ice, and under the ba-

rometric pressure of $0^{m}\cdot76$ (= 29·922 inches) to be 10462. From which it appears that if G be the measure of gravity at the place where this experiment was made (the Observatory of Paris), the value of $\frac{\varpi}{D}$ is $0^{m}\cdot76 \times 10462$ G, or $7951\cdot12 \times$ G. For any other place this quantity must be multiplied by the ratio of the force of gravity at that place to the force represented by G. The numerical value of G is $9^{m}\cdot80896$, equivalent to 32·1824 English feet. The above coefficient of G is obtained on the supposition that the air is perfectly void of moisture. It has been ascertained, by a process which will be touched upon at a subsequent part of the Report, that the ratio of the density of air completely saturated with vapour, to air perfectly dry under the same pressure, is 0·99749. On multiplying $7951^{m}\cdot12$ by this factor the result is $7971^{m}\cdot09$, which applies to air containing its maximum quantity of humidity. The mean of the two values, $7961^{m}\cdot10$, may be supposed to apply to the usual state of the atmosphere. Its equivalent in English fathoms is 4353·26. A correction should also be given to the factor 0·00375, on account of the effect of vapour. When the temperature increases the quantity of vapour in the atmosphere augments at the same time, and as the density of vapour under the same pressure is greater than that of air, a given quantity of humid air will dilate more than an equal quantity of dry air: it has been usual in consequence to change the above factor to 0·004. As the temperature hitherto spoken of is always that indicated by the air thermometer when a mercurial thermometer is employed, a correction may be thought necessary, on account of the different rates of expansion of mercury and air. The experiments, however, of MM. Petit and Dulong show that this correction is insensible between 0° and 100° centigrade, and only begins to be of considerable magnitude at a temperature of 300° centigrade*. Within the same limits the increase of elastic force was found to be proportional to the increase of temperature, the volume being constant†.

By the means above indicated, one relation between the pressure, density, and temperature of an aeriform body has been experimentally assigned, and the two constants which the equation expressive of this relation involves have been determined with great exactness. But in addition to this equation the mathematician requires another for the solution of any question in which the effect of variation of temperature is to be taken into account. For instance, if it were proposed to determine the

* Memoir on the Dilatation of Gases. *Journal de l'Ecole Polytechnique*, cah. 18. p. 213.

† p. 200 of the same Memoir.

pressure of the atmosphere at any assigned altitude above the earth's surface, in other words, to solve the problem of the *barometric measurement of heights*, a second equation, expressing the relation of the temperature to the density or the pressure, would be required. For want of such an equation, Laplace assumes, in investigating his formula for the determination of heights by the barometer*, that the temperature is uniform, and equal to the mean of the observed temperatures at the higher and lower stations. This supposition, as Mr. Ivory has shown †, conducts to the same barometric formula as would result from supposing the decrements of atmospheric temperature to be equal for equal increments of height above the earth's surface.

The only attempt I know of which has been made to collect the law of variation of temperature at different heights in the atmosphere from observations, is that by Mr. Atkinson in his Memoir on Astronomical Refractions contained in the second volume of the Transactions of the Royal Astronomical Society. His object is to arrive at the law by a consideration of as many recorded observations as could be procured of temperatures in different latitudes and different elevations (principally those of General Roy ‡ and Baron Humboldt §), by a discussion of which he comes to the conclusion, that for equal decrements of temperature the increments of height are in arithmetic progression. The following is the table of results given at p. 189 of the Memoir, from Humboldt's Observations in South America:

Height.	Depression of Therm.
3724 Feet	14°·070 Fahr.
6740	23°·310
9029	30°·070
10790	34°·715
15744	49°·620
19286	57°·380

The same arithmetic progression results from the observations in Europe as from those in South America, and the general empirical formula connecting the height h (expressed in feet) and the depression n (expressed in degrees of Fahrenheit) below the temperature at the earth's surface, is the following:

$$h = \left\{251\cdot 3 + \frac{3}{2}(n-1)\right\} n.$$

* *Mécanique Céleste*, liv. x. chap. iv. §. 14.

† Philosophical Transactions, 1823, p. 455.

‡ Phil. Trans. 1777, part ii. p. 653.

§ Memoir on Isothermal Lines, in the *Mémoires d'Arcueil*, tom. iii. p. 462; translated in Edin. Phil. Journ., vols. iii., iv., v.

If this law, which requires confirmation by observations more in number, and extended over a greater portion of the earth's surface, should be finally established, the usual formula for the barometric determination of heights will require some modification. The mathematical reasoning in this problem ought also in strictness to proceed on the supposition that the atmosphere is in motion, and not, as is always supposed, at rest; but this improvement in the theory is not likely to be effected till at the same time a mathematical theory of the periodic oscillations of the barometer can be given.

It remains to notice the attempts of a purely theoretical character which have been made to furnish the second equation above spoken of, and by it to assign a relation between the temperature, pressure, and density of the air at different elevations. If we conceive the atmosphere to be at rest, and every point of it to be in its mean state with respect to temperature, there will be a certain temperature corresponding to a certain density; in other terms, the density will be a function of the temperature. Now by experiment it is found that when a given mass of air is suddenly rarefied by mechanical means, at the first instant, before it receives any accession of heat from surrounding bodies, its temperature is lowered, and it is supposed to absorb a quantity of heat equal to the diminution of temperature. The heat that has disappeared is conceived to become latent, while the total quantity of heat, consisting of the latent heat, and that indicated by the thermometer, remains the same in the given mass, till the temperature is raised by the position of the mass in the midst of bodies of a higher temperature. Dr. Dalton conceived the condition of the air in this experiment at the first moment of rarefaction to be analogous to that of air of the same state of rarefaction in the atmosphere, and consequently infers that to the same quantity of atmospheric air the same quantity of heat is always attached, a loss of temperature being compensated for by an increase of latent heat, or, as it is also called, heat of combination, and an increase of temperature being due to a development of latent heat. Admitting, therefore, that the density of the atmosphere is a function of the temperature, it will follow from this hypothesis that it is also a function of the latent heat. The truth of this theory can be judged of only by its forming a basis for mathematical calculation, and so allowing us to compare the consequences that flow from it with experience. Mr. Ivory has enabled us to judge of it in this manner by a series of valuable papers on this subject contained in the 66th volume of the Philosophical Magazine*. Mr. Ivory admits with Dr. Dalton

* pp. 12, 81, 241.

that the density is a function of the heat of combination, without allowing that the loss of temperature is exactly equal to the heat that enters into combination in the latent form. His reasoning is in fact conducted on the supposition that the loss of temperature is equal to the heat of combination, diminished by heat from extraneous bodies. To ascertain the function that the density is of the latent heat, he avails himself of a well-known experiment, first made by MM. Clement and Desormes, and repeated afterwards by MM. Gay-Lussac and Welter, which determined the ratio of the specific heat of air submitted to a constant pressure to its specific heat when retained in a constant volume. This ratio Gay-Lussac found to be nearly of constant value between the temperatures $-20°$ and $40°$ of the centigrade thermometer, and between the pressures $0^{m}\cdot 144$ and $1^{m}\cdot 46$. By assuming it to be constant, Mr. Ivory arrives at the function he is seeking for, and further, supposing the heat from extraneous sources to vanish, i. e. by returning to the Daltonian hypothesis, he is conducted to a very simple relation between the pressure and the density expressed algebraically by the equation $p = \rho^m$, where p is the pressure relative to a unit of pressure, ρ the density relative to a unit of density, and m the ratio just spoken of. This same equation M. Poisson had previously obtained* by means of the same experimental results, but without the consideration of latent heat, as I shall afterwards have occasion to mention. As the effect of heat in determining the atmospheric density and pressure is taken into account in this equation, if it be a true equation, it will be that additional one which is required for the complete solution of problems, such as the barometric measurement of heights. It is, therefore, important to inquire whether the equation $p = \rho^m$ expresses the law of nature. By pursuing the investigation, on the supposition that the total heat of a mass of air is made up of the latent heat, the heat of temperature, and extraneous heat, and joining to expressions previously obtained for p and ρ, the usual differential equation $dp = -g\rho\, dz$ relative to the pressure, density, and altitude (z), Mr. Ivory arrives at an equation (Phil. Mag., vol. lxvi. p. 242) by which the hypothesis of Dalton may be put to the test. He finds that there are an unlimited number of suppositions all equally leading to an equation of the form $p = \rho^m$, m being different for each, and all indicating different atmospheres, which possess the common property of decreasing in temperature, at a rate proportional to the increase of altitude. If $m = 1$, and consequently $p = \rho$, the decrement of temperature is infi-

* *Connaissance des Tems* for 1826, published in 1823.

nitely slow, or the temperature is uniform. If $m = 1\cdot375$, which is the ratio of the specific heats in Gay-Lussac's experiment, and consequently the value of m on Dalton's hypothesis, because the air on this supposition possesses the greatest possible degree of cold that can be produced by rarefaction, the calculated amount of decrement of temperature is 1° centesimal for an altitude of $67\frac{1}{2}$ fathoms, and the total height of the atmosphere is 20 miles. But according to Mr. Atkinson's memoir, 1° is the real amount of depression in the first 80 fathoms of ascent. Mr. Ivory adopts 90 fathoms from the temperature observed in Gay-Lussac's balloon ascent, and derives $\frac{5}{4}$ for the corresponding value of m. From all this it appears that the theory we are examining, being pursued by mathematical reasoning to its consequences, is shown to be an approximation to fact, but not accurately true, because it assigns too large a rate of decrement of temperature to the lower strata of the atmosphere; and, if Atkinson's formula be correct, it errs also in giving a uniform instead of a decreasing rate of decrement in ascending to the higher regions.

Mr. Ivory, in his celebrated paper* on astronomical refractions, has pursued a different train of reasoning with reference to this subject. He there sets out with supposing the decrements of temperature to be equal for equal increments of height, and is readily conducted (p. 437) to an equation equivalent to $p = \rho^m$. When the value $\frac{5}{4}$, derived from Gay-Lussac's ascent, is substituted for m, this equation answers very well the purpose of calculating a table of refractions, and gives them with great accuracy for altitudes very little above the horizon. It does not come within the province of this Report to speak of the problem of astronomical refraction, excepting so far as it bears upon the constitution of the atmosphere; I shall therefore only remark that a comparison of refractions, determined by astronomical observations with refractions calculated on any theory of the constitution of the atmosphere, does not serve as a good test of the truth of the theory. It results from the reasoning in the *Mécanique Céleste*†, that as far as 74° of zenith distance the calculated amount of refraction agrees very nearly with the observed, independently of any assumed law of decrease of density. Dr. Brinkley showed the same thing in a more direct manner‡, and obtained a formula, the error of which at 80° 45′ of zenith distance does not amount to half a second, whatever be the variation of density in the atmosphere. When the comparison is

* Phil. Trans., 1823, p. 409.

† liv. x. c. i.

‡ Transactions of the Royal Irish Academy, 1815, vol. xii. p. 77.

made for altitudes nearer the horizon, the differences between the calculated and real refractions are of considerable amount, in cases where the calculations have proceeded on suppositions relative to the constitution of the atmosphere very remote from the truth, and suffice to detect their inaccuracy. But it appears from Mr. Ivory's reasoning, that if p be assumed proportional to $\rho^{\frac{5}{4}}$, and the refractions be calculated accordingly, they come out very nearly true quite close to the horizon. It would, however, be wrong to conclude from this that the equation $p = \rho^{\frac{5}{4}}$ represents the law of nature, for the whole height of the atmosphere calculated by this formula is found to be twenty-five miles, which in all probability is far below the truth*. The fact is, astronomical refractions are very little influenced by the higher parts of the atmosphere, so that supposititious atmospheres agreeing with the existing atmosphere in the lower strata, and widely differing in the upper, may yet produce the same amount of refraction†.

For the reasons given above no definite relation between the pressure, density, and temperature of the air can be extracted either from the observation of astronomical refractions or from the theory of them. The only method that seems to be open for increasing our knowledge of the constitution of the atmosphere (and by consequence of elastic fluids in general) is to multiply thermometrical observations at various heights and different stations, for the purpose of determining the law of the mean distribution of temperature, and how far the variation from one point to another depends on the variation of density alone. Something in this respect may possibly be gathered from the subject which next claims our attention.

Theory of the Velocity of Sound.—The difference between

* In place of the equation $p = \varrho^m$, Mr. Ivory assumes another, viz., $p = (1-f)\,\varrho^{1+\frac{1}{n}} + f\varrho^2$, f being an arbitrary quantity, which may have such values assigned to it that the rate of decrease of temperature shall be slower as the height increases, and the total height of the atmosphere be of any value from twenty-five miles to infinity. This formula he employs in calculating refractions, and finds them sufficiently accurate by taking $f = \frac{1}{4}$ and n infinitely great, which corresponds to an unlimited atmosphere, supposing the force of gravity to be the same at all heights.

† The memoir of M. Biot on astronomical refractions, read before the Paris Academy, Sept. 5, 1836, and printed in the additions to the *Connaissance des Tems* for 1839, treats the problem with all the generality and precision that may be hoped for on a subject of this nature. I advert to the memoir here, chiefly because its first part, on the conditions of the equilibrium of the atmosphere, contains a lucid exposition of the mode of mathematically estimating the effects of temperature, and of the mixture of aqueous vapour in the air.

the observed velocity of sound and that which Newton derived from the law of Mariotte (amounting to nearly a sixth of the whole), has given rise to researches and experiments of a very interesting nature, in which the philosophers of France have chiefly signalized themselves. The first attempts to account for this difference were unavailing. Newton did not succeed. Euler supposed that as the Newtonian formula was obtained by neglecting powers of the velocity of the aerial particles higher than the first, the difference was attributable to an imperfect approximation. But Lagrange showed that the velocity of propagation in the hypothetical fluid, of which the pressure varies in the same proportion as the density, is the same for large excursions of the vibrating particles as for small. Lagrange also remarked that he could explain the discordance between the theory and experiment by supposing the pressure of the air to increase more rapidly than its density, but was deterred from arguing on this supposition, as he considered it contradicted by the law of Mariotte. The true solution was reserved for Laplace, who first remarked that the excess of the experimental velocity above the theoretical was owing to the development of heat and production of cold which accompanies every very sudden compression and dilatation of the air, and which was not taken into account in the theory. This may perhaps be considered the most successful explanation of a natural phænomenon that has been given in modern times. The cause assigned was a *vera causa*, one that may be presented to our senses, and therefore perfectly intelligible. A very common experiment by which a combustible substance is inflamed by the sudden compression of air, leaves no room to doubt of the reality of the development of heat under the circumstances contemplated in the theory. This explanation was known to be Laplace's a considerable time before its author published anything expressly in writing respecting it. An article by M. Biot in the *Journal de Physique*, 1802, and the memoir of M. Poisson on the Theory of Sound*, which was written in 1807, contain, I believe, the first applications of analysis to Laplace's Theory. Anterior to such application it is necessary to make some supposition for the purpose of connecting the effect of the developed heat with the other elements of the problem. That which Biot and Poisson adopted is thus expressed by the latter :—" In the propagation of sound, the compression or dilatation which takes place successively in the whole extent of the mass of air being very small, we may regard the augmentation or diminution of temperature due to this

* *Journal de l'Ecole Polytechnique*, cah. xiv.

change of density as being proportional to it." By aid of this consideration he arrives at the following equation:

$$a = \sqrt{\frac{g\,h}{\mathrm{D}} \cdot \left(1 + \frac{\alpha\,\omega}{(1 + \alpha\,\theta)\,\gamma}\right)},$$

in which a is the velocity of sound, g the force of gravity, $g\,h$ the pressure of the air on a unit of surface, when its density is D and temperature θ, and ω the increment of temperature caused by the sudden condensation γ. At the time this memoir was written no experiments had been made by which the rise of temperature, caused by a given small and sudden condensation, could be determined. M. Poisson therefore reverses the question, and infers the increment of temperature from the observed velocity of sound. He finds that if the dilatation or compression were $\frac{1}{116}$ of the whole volume, the temperature would be depressed or elevated one degree of the centigrade thermometer. In the volume of the *Annales de Physique et de Chimie* for the year 1816, Laplace published the following theorem without the demonstration: "The velocity of sound is equal to the product of the velocity which the Newtonian formula gives, by the square root of the ratio of the specific heat of air when the pressure is constant to its specific heat when the volume is constant." The proof was first given in the *Connaissance des Tems* for 1825, and afterwards in the fifth volume of the *Mécanique Céleste;* previous to which the experiment* of Clement and Desormes, before mentioned, had furnished the means of instituting a numerical comparison between the theoretical and the observed velocity of sound. This experiment was in fact a practical imitation, as near as could be, of what was supposed to take place in aerial vibrations. If specific heat be defined to be the quantity of heat required to raise the temperature 1° under given circumstances, the datum furnished by the experiment is the ratio of the specific heat under a constant pressure to the specific heat under a constant volume. It is convenient to speak of it in these terms though the consideration of specific heats is not absolutely necessary in this question, as we shall presently see. By whatever terms it be denoted the datum is one which experiment alone can furnish, and without it no numerical comparison can be made

* See the Memoir in the *Journal de Physique* for November, 1819. This memoir, which was composed in competition for the prize awarded by the French Institute in 1813 to MM. Delaroche and Berard, contains in addition to the detail of experiments made with reference to the subject proposed by the Institute, viz., the specific heat of gases, the views of the authors respecting the absolute caloric of space and the absolute zero of caloric.

between the theoretical and observed velocities of sound. The result of the comparison, first made by Laplace, was, that the theoretical determination fell short of the observed value by $7^{m}\cdot 5$. A difference of this kind was to be expected, as it was impossible to perform the experiment so rapidly that some of the developed heat would not escape through contact of the air with the containing substances. The ratio of the specific heats, as obtained by MM. Clement and Desormes, is 1·354. Gay-Lussac, on repeating their experiment with great care, and under circumstances a little different, found 1·375, which brings the observed and theoretical velocities something nearer, but the latter still falls short of the other.

The mathematical theory* of Laplace is prefaced by certain theoretical considerations respecting free and latent heat, and the mutual action of the molecules of bodies and their caloric; which are subsequently introduced into the investigation for determining the velocity of sound†. It is proper, however, to observe that the solution of this problem is not necessarily connected with any considerations either of latent heat or of specific heats. This is sufficiently apparent from what M. Poisson has written on the subject. In the first of two excellent papers (contained in the volume of the *Annales de Chimie et de Physique* for 1823), which place in a simple point of view all that has been most satisfactorily established with reference to the question before us, this author deduces the velocity of sound, by means of the usual experimental data, from the formula obtained in his Memoir on the theory of sound, which, as was said before, rests on the single assumption that the increment of temperature is proportional to the condensation, without employing any additional hypothesis whatever, and without any mention of specific heats or of latent heat. In the same paper he goes on to show, by adopting the definition of specific heat stated above, and by further supposing that for small changes of temperature the absolute quantity of heat gained or lost is proportional to the rise or fall of the thermometer, that the

* *Mécanique Céleste*, liv. xii. chap. iii.

† Laplace has also supposed (liv. xii. chap. iii. art. 7,) that $\frac{d\varrho c}{\varrho c} = (1-\beta)\frac{d\varrho}{\varrho}$, ϱ being the density of the gas, c the free caloric which has a sensible effect on the thermometer, and β a positive constant. This equation is not deduced from anterior considerations. It follows from it that $\frac{dc}{c} = -\beta\frac{d\varrho}{\varrho}$, and consequently that the free caloric increases as the density diminishes.

quantity expressed by $1 + \frac{\alpha \omega}{(1 + \alpha \theta)\gamma}$ is equal to the ratio of the specific heat under a constant pressure to the specific heat under a constant volume. From the reasoning of M. Poisson we may therefore infer, that for the theoretical explanation of the excess of the velocity of sound over the Newtonian determination one assumption only is absolutely necessary, viz., that the changes of temperature produced by sudden small variations of density are, for a given temperature of the air, proportional to those variations; but if the consideration of specific heats be introduced, that it is necessary also to suppose the small variations of absolute heat to be proportional to the corresponding variations of temperature.

Mr. Ivory has written on this question some things well deserving of notice. In a paper before referred to* he deduces the velocity of sound from the formula $\frac{p}{p'} = \left(\frac{\rho}{\rho'}\right)^m$, which he had previously arrived at by considerations already stated, and finds it equal to $V\sqrt{m}$, V being the velocity obtained according to the law of Boyle and Mariotte. This is the same value that is given by other methods, since the index m is the ratio of the specific heats. When the above equation is employed with reference to the variation of density in the atmosphere and to astronomical refractions, the value of m that best accords with phænomena is nearly 1·25, as we have seen, instead of 1·375. This seems to prove that the law of nature is not expressed under all circumstances by the same formula, and that one which applies very well to sudden changes of density of the air in motion is inapplicable to those that are permanent, like the variations of density of the atmosphere at rest depending on the height above the earth's surface.

Afterwards, in 1827†, Mr. Ivory applied to the problem a different kind of reasoning on the following principles. First, it was admitted that equal quantities of absolute heat produce equal increments of volume: secondly, that the rise of temperature is proportional to the increment of volume according to the indications of the air thermometer: thirdly, that the absolute heat is equal to the sum of the latent heat, and the heat of temperature. From which it follows that the increment of latent heat is also proportional to the increment of volume; hence if ν be the volume when the temperature is 0, ν' the volume

* Phil. Mag., vol. 66, p. 12.

† Phil. Mag. and Annals, vol. i. pp. 91 and 251.

when the temperature is τ, i the increase of latent heat accompanying the change of volume from v to v', and α, β, two constants, it will be seen that

$$v = v'(1 + \alpha\tau), \text{ and } v = v'(1 + \beta i).$$

Hence $\alpha\tau = \beta i$, or $\frac{\alpha}{\beta} = \frac{i}{\tau}$. The first of the expressions for v supposes the volume to change under a constant pressure; the other obtains in whatever way the change of volume takes place. The ratio of i to τ is the ratio of the heat absorbed by a mass of air, or become latent, by a given sudden rarefaction, to the heat of temperature required to expand the mass to the same degree of rarefaction. This ratio can therefore be inferred from the experiment of Clement and Desormes, so often cited; and as α is known, β may also be found. The absolute heat required to produce a rise of temperature τ under a constant pressure is, according to this theory, $\tau + i$; and that required to cause the same rise of temperature when the volume is constant is τ. Hence $\frac{\tau + i}{\tau}$ is the ratio of the specific heats; and admitting Laplace's theorem, the factor by which the Newtonian velocity of sound must be multiplied is $\sqrt{1 + \frac{i}{\tau}}$ or $\sqrt{1 + \frac{\alpha}{\beta}}$. Mr. Ivory finally observes* that the main element on which the solution of the problem must turn, by whatever process the result is brought out, is the quantity of heat extricated from air condensed in a given degree; and accordingly he proceeds to investigate in an independent manner, the relation between the elasticity and density of a mass of air that varies its temperature as it dilates or contracts, without losing or receiving any heat by means of the surrounding medium. This investigation conducts to the following relation between the pressure and the density

$$\frac{p}{p'} = \frac{\rho}{\rho'}\left(1 + \frac{\alpha}{\beta}\right) - \frac{\alpha}{\beta},$$

from which the velocity of propagation of sound is arrived at by the usual process, the factor being $\sqrt{1 + \frac{\alpha}{\beta}}$ as before. From

* Phil. Mag. and An., vol. i. p. 252.

the above relation between p and ρ, Mr. Ivory infers (p. 255) that the ratio of the specific heats is not a constant ratio for large variations of density and temperature*.

The principle on which the effect of moisture contained in the air is introduced into the theoretical determination of the velocity of sound, is derived from Dalton's theory of mixed gases. If two quantities, v, v', of two gases under the same pressure p, and of the same temperature θ, be put into a space $v + v'$, the gases will penetrate into each other and become perfectly mixed, so that the proportional parts will be everywhere the same in the same space. Also the temperature and pressure of the mixture will be p and θ, the same as those of the constituents. From these facts, established by experience, may be derived by reasoning as Poisson has done in the second of his papers in vol. xxiii. of the *Annales de Chim. et Phys.*, p. 348, the following law, which experience also confirms :—"The pressure of a mixture of gases and vapours will always be the sum of the pressures which these fluids would support separately at the same temperature, and the same in volume as the mixture." The atmosphere in its usual state is a mixture of dry air and vapour of water. It is found that the maximum of aqueous vapour formed in a vacuum at the temperature $18^\circ{\cdot}75$ C, is measured by the barometric height $0^{m}{\cdot}016$, and by the preceding law the same height of the barometer would measure the elastic force of vapour formed at the same temperature in dry air of the ordinary pressure $0^{m}{\cdot}76$, and increase the pressure to $0^{m}{\cdot}776$, since the maximum of vapour, that is, the greatest quantity which the given temperature allows to be formed, is the same in the two cases. Gay-Lussac has inferred from his experiments, that if aqueous vapour could be raised from the tension $0^{m}{\cdot}016$ to $0^{m}{\cdot}76$ without liquifying, its density would be to that of dry air, under the same pressure and at the same temperature, as 5 to 8. Hence in general, if D be the density of dry air, D′ that of moist air under a given barometric pressure h, and at a given tempe-

* An equivalent relation between p and ρ may be obtained in another manner, which I have adverted to in a communication to the No. of the Phil. Mag. and Annals for May, 1830, and have since developed more fully in a paper recently read before the Cambridge Philosophical Society; viz. by assuming the velocity of propagation of sound to be constant when the temperature is given, and then joining with the usual equations of fluid motion, a general expression for uniform propagation, which may be arrived at independently of the consideration of temperature. When the resulting equation between p and ρ is used for finding the velocity of propagation, it gives an expression agreeing with that obtained on the supposition of a constant ratio of the specific heats, when the condensations and rarefactions are small, but diverging from it as they become larger.

rature, and n be the tension of the vapour which the moist air contains, the density of the air in the mixture will be $D\left(1-\frac{n}{h}\right)$ that of the vapour $D\,\frac{5n}{8h}$, and consequently the density of the compound D' is equal to $D\left(1-\frac{3n}{8h}\right)$. Thus the actual density is given in terms of the density of dry air under the same pressure. In any instance to which this expression is applied, the quantity n will have to be determined by observation of the hygrometer.

The manner in which the theoretical formula for determining the velocity of sound is brought to the greatest possible degree of perfection having been now exhibited, it will be interesting to compare the result it gives with the most accurate experiments. Those which claim the greatest confidence in this respect are the experiments undertaken by Professor Moll, of Utrecht, and Dr. Van Beek in June 1823, a detail of which is contained in the Philosophical Transactions of the Royal Society for 1824 (p. 424.) Measures were taken to secure that the firing of the guns at two stations should take place as nearly as possible at the same instant, which was effected with much greater precision in these experiments than in those of the French Academicians in 1822. By this precaution the cause of error arising from the wind is removed, the velocity of propagation in still air being assumed to be the arithmetic mean between the velocities inferred from the observations at the two stations, as in fact it might be shown to be theoretically. The difference between two determinations on different days, when this precaution was attended to, was only 2·166 feet, whereas two other determinations on different days, when the shots were not reciprocal, differed by 20·84 feet. The mean velocity which the experiments gave for dry air at 0° of temperature was $332^{m}\cdot05$ (= 1089·744 English feet). The mean excess of the experimental determination over the theoretical, supposing the ratio of the specific heats to be 1·3748*, was $4^{m}\cdot58$ (= 15·032 feet).

In Dr. Gregory's experiments†, made in 1823, an anemometer was employed whose indications were found to agree with the velocity of the wind, as inferred from the difference of the velo-

* It is shown by Dr. Simons (Phil. Trans., 1830, p. 213.) that the mean value of this ratio as derived from the experiments of Drs. Moll and Van Beek is 1·4152.

† Cambridge Philosophical Transactions, vol. ii. p. 119.

cities of sound when aided, and when opposed by the wind. The experiments were made with intervals between the stations, varying from less than half a mile to $2\frac{1}{2}$ miles, and in temperatures varying from 27° to 66° Fahr. The mean of eight results reduced to the temperature of freezing is stated by Sir John Herschel (Art. SOUND, *Ency. Metrop.*) to be 1088·05 feet. The velocity observed at the temperature of freezing was 1090·17 feet.

A valuable series of experiments was made by Mr. Goldingham, at Madras, in 1820, extending through every month of the year. The following is a table of the mean temperature and mean determination of velocity for each month.

Month.	Mean Height of Thermometer.	Velocity in a Second.	Month.	Mean Height of Thermometer.	Velocity in a Second.
	°	ft.		°	ft.
January ..	79·05	1101	July	86·65	1164
February..	78·84	1117	August ..	85·02	1163
March....	82·30	1134	September	84·49	1152
April	85·79	1145	October ..	84·33	1128
May	88·11	1151	November	81·35	1101
June	87·10	1157	December	79·37	1099

It is interesting to observe, as the author remarks, "how regularly the mean velocity proceeds to a maximum about the middle of the year, and afterwards retraces its steps, giving us a velocity in one case of 1164 feet in a second, and in the other of only 1099 feet. This regularity would, no doubt, be still greater with the mean of the observations of several years." In these experiments (which have been compared with theory by Mr. Galbraith*) the indications of the barometer and hygrometer were noted; and though the experiments were not made by simultaneous reports, the effect of the wind may be considered to be completely eliminated in the mean of the observations of the whole year. It is worthy of remark that the difference between the greatest and least velocities is much more considerable than, according to theory, would be due to the corresponding difference of temperature. The greatest and least indications of the hygrometer were 27·85 and 1·43, the former in July and the other in December, the two months in which the velocity of sound was greatest and least. Sir John Herschel gives as the mean determination from the total of Mr. Goldingham's experiments reduced to the temperature of freezing, a velocity of

* See *Phil. Mag.* vol. lxvi. p. 109, and vol. lxviii. p. 214.

1086·7 feet. This must be considered as applying to the mean state of the hygrometer, the nature of which not being stated, its indications could not be made use of.

Experiments were made by Captain Parry and Lieut. Foster expressly to determine the effect of low temperatures on the velocity of sound*. The following is a mean of results.

Therm. Fahr.	$-41^{\circ}\cdot3$	$-33^{\circ}\cdot3$	$-27^{\circ}\cdot2$	$-21^{\circ}\cdot0$	$-20^{\circ}\cdot0$	$+33^{\circ}\cdot3$
Velocity in feet per Second.	985·9	1011·2	1009·2	1031·0	1039·8	1069·9

A comparison of the velocities at the highest and lowest temperatures differing by $74^{\circ}\cdot6$, gives an increase of velocity of 1·126 feet for each increase of temperature by 1° of Fahrenheit. A like comparison of the velocity at the lowest temperature, $-41^{\circ}\cdot3$, with the velocity in Mr. Goldingham's experiments at the temperature 87°, gives an increase of 1·35 feet for each degree of Fahrenheit.

The experiments of Captain Parry and Lieut. Foster at Port Bowen in 1824—1825 have been compared with the theory by Professor Moll†. On using the coefficient 1·375, the velocity given by the theory falls short of the experimental value by 17·47 feet, a difference exceeding that resulting from a like comparison of the experiments in the Netherlands by something less than 2½ feet. In the arctic experiments the state of moisture in the air was not noted; but Professor Moll shows that this omission is productive of a very small error in very low temperatures. The near agreement of experiments made under circumstances so widely different, must lead us to suspect, as Professor Moll justly observes, that the difference which still remains between the results of computation and observation are to be ascribed to some imperfection in the theoretical formula, and not to any fault in the observations‡.

In 1828 M. Dulong§ read a memoir on the specific heats of elastic fluids, which requires to be noticed in conjunction with

* See p. 235 of the Supplement to the Appendix of Captain Parry's Voyage in 1819—1820.

† *Phil. Trans.* 1823, p. 97.

‡ For a synoptical view of the results obtained by different observers, the dates of their observations, and the circumstances under which they were made, I may refer to a table in Art. 16 of Sir John Herschel's Treatise on Sound in the *Encyclopædia Metropolitana*.

§ *Mémoires de l'Institut*, tom. x. p. 147.

the subject before us. M. Dulong takes for demonstrated that the square of the quotient of the real velocity of sound in any elastic fluid whatever, divided by the velocity calculated according to the formula of Newton, is equal to the ratio of the specific heat for a constant pressure to the specific heat for a constant volume. His object is to find this ratio for different elastic fluids, which, it is plain, may be inferred, according to this theorem, from the real velocity with which sound is propagated in them. It is not possible to obtain these velocities for any other elastic fluid than atmospheric air, excepting by indirect means. M. Dulong avails himself of a method which had been previously employed by various experimenters, but not with complete success, as was evident from the discordant results they obtained. The method consists in determining the velocity of propagation from the musical note rendered by a given cylindrical tube, and from the measured distance between two consecutive nodal sections or positions of minimum vibration, which interval he calls the length of a *concameration*. The pitch of the note gives the number of vibrations in a given time, and consequently the time of propagation over the measured interval, and therefore the velocity of the sound. By pursuing a process different from any that had been adopted before, M. Dulong is enabled to give great precision to this method. He first operates on atmospheric air, with the view of ascertaining the accuracy which the method admits of. By various trials, each more exact than the preceding, he obtains results, all of which fall short in a small degree of the velocity obtained by direct observation, and accordingly comes to the conclusion that the relation indicated by theory between the velocity of sound in free air, and the length, such as it can be observed, of the concamerations that are formed in a flute-tube, is not verified exactly. He hints at some experiments proper for making evident the cause of this discordance, but I am not aware that any such have been published.

As this method fails in giving exactly the ratio of the specific heats of atmospheric air, M. Dulong adopts a ratio (viz. 1·421) which he says "is the mean of a great number of direct observations made in free air by different observers." I mention this particularly, as it seems to have been supposed* that Dulong

* M. Poisson's excellent Treatise on Mechanics is a work so extensively used that it is desirable to point out any error that may have inadvertently crept into it. I do not therefore scruple to advert to an inaccuracy in p. 716, tom. ii. (2nd ed.), where the author asserts that the ratio 1·421 is deduced from observation of the sound produced by air inclosed in a tube, and endeavours to account for the excess of this value above another derived from the propagation of sound in free air, by the different radiation of heat in the two circumstances. This is contradicted by the assertion quoted above from Dulong's Memoir.

obtained this ratio from his own experiments. In the next place he establishes, contrary to an opinion previously expressed by M. Biot, that with gases very different in their physical properties, such as hydrogen gas and carbonic acid gas, the nodal sections are exactly in the same positions in the same tube. This is an important fact with reference to the theory of vibrations of aeriform fluids in tubes, from which it readily follows that the *relative* velocities of propagation of different elastic fluids may be inferred from the musical notes they give out from the same tube; and taking the ratio of the specific heats of air to be that determined by direct observations on sound, the ratios for the other fluids will be immediately deduced from these velocities. Representing in general the ratio of the specific heats by $1 + f$, the quantity f is taken by Dulong to be the measure of the thermometric effect produced by sudden and equal changes of density of the several fluids; then assuming the thermometric effects thus developed to be inversely as the specific heats under a constant volume, he is furnished with numbers to express these specific heats, that of air being expressed by unity. Hence by means of the ratios of the specific heats obtained as above mentioned, numbers expressive of the specific heats under a constant pressure are also arrived at, that of air being again taken for the unit. These last numbers, compared with those which Berard and Delaroche* obtained by direct experiment, are found to agree with considerable accuracy. In concluding this part of the subject I cannot forbear remarking, in the words of Dulong, "how much science owes to the natural philosophers who direct their labours towards giving more and more precision to the determination of the numerical coefficients which become theoretical elements of constant use." Such are the numerical measure of the force of gravity; the ratio of the density of mercury to that of air; the coefficients of the dilatation of mercury and of the gases; the ratios of the densities of elastic fluids; the actual velocity of sound in air. All these constants, together with the exact length of the aerial vibrations corresponding to a given musical note, have been employed in arriving at the principal conclusion contained in the valuable memoir which has been the subject of the preceding remarks.

Propagation of Sound through Liquids.—The experiments of Canton, of Œrsted, and Colladon and Sturm have ascertained the degree in which water is compressible, and proved that for small changes of volume the compressions are proportional to the compressing forces. This law seems to indicate that the

* *Annales de Chimie*, tom. lxxxv. pp. 72 and 113.

pressure in the interior of liquids is a function of the density, (at least at distances from their surfaces greater than the radius of the sphere of the molecular action). For admitting this to be the case, it will be a simple analytical consequence, that the *small* variations of pressure are proportional to the corresponding variations of density, whatever be the form of the function which connects the pressure and density together*. The knowledge of the degree of compressibility of water or of any other liquid, furnishes the means of determining the velocity with which sound is propagated in it. This application of the experimental determination of compression has been made by Dr. Young† and Laplace, who have each given a formula by which, when the contraction is known for a given pressure, the velocity of propagation can be calculated. Poisson has also given a demonstration of the formula in question‡, which, it appears, applies as well to solids as to liquids. If D be the density of the solid or liquid, k the length of a cylindrical column of it under a known pressure, ε the small diminution of this length by a given increase of pressure P, then the velocity of propagation will be $\sqrt{\frac{P k}{D \varepsilon}}$. This formula has been put to the test by experiments made in the lake of Geneva by M. Colladon in 1826§. On observing that the sound of a bell struck a little below the surface of the water was not audible out of the water at considerable distances from the point of disturbance, but appeared to be deflected downwards when it fell very obliquely on the water surface, it occurred to him to place a little below the surface a metallic plate, with its plane vertical and perpendicular to the direction of the sound, surmounted by a conical tube, to the end of which when the ear was applied the sounds caught by the metal plate were audible when they came from a distance of 13487 metres. The sound traversed this distance in 9·4 seconds, consequently the velocity was 1435 metres in a second. By calculating the velocity given by the formula with due attention to all the circumstances that might affect the accuracy of the result, M. Colladon finds 1428 metres. The difference between this and the experimental value falls within the limits of the possible errors of observation, and the accordance of the theory with fact may

* Experiments on alcohol and sulphuric æther show a sensible diminution of contraction for high pressures. See the Essay of MM. Colladon and Sturm, *An. de Chim. et de Phys.*, tom. xxxvi. p. 144—147.

† *Lectures on Natural Philosophy*, vol. ii. p. 69.

‡ *Mémoires de l'Institut*, An 1819, p. 396—400.

§ *An. de Chim. et de Phys.* tom. xxxvi. p. 242.

therefore be pronounced to be satisfactory. As the formula was obtained without taking into account the effect of the development of heat, we may infer from the small difference between the above results, that this effect, if not wholly insensible, is of very small amount. M. Colladon remarks respecting the nature of the sound transmitted through the water, that when caused by the striking of a bell, it was heard as a sharp and dry sound, resembling the striking of two knife-blades against each other. This fact seems to prove with respect to liquids, what is also most probably true of solids, that the relation between their density and pressure is such as not to allow the condensations arising from any disturbing cause to be transmitted to great distances exactly in the order and proportion in which they are originally impressed, in the same manner as when the pressure varies in the simple ratio of the density. On this account probably, as well as by reason of their great density, liquids and solids are not vehicles so proper for conveying vocal sounds as aeriform fluids.

Theories of Elastic Fluids.—A few words must now be said on those refined theories respecting elastic fluids, which, proceeding upon certain hypotheses of their ultimate constitution and the action of molecular forces, are directed to the purpose of accounting by mathematical reasoning for certain of their fundamental properties, with which we have originally become acquainted by experience only. Such a theory is that at the commencement of the 12th book of the *Mécanique Céleste*, to which allusion has already been made. The leading principles of this theory are of the following nature. Each molecule of a body, whether in the solid, liquid, or aeriform state, is submitted to the action of three forces: 1°. The repulsion of its caloric by the caloric of the other molecules. 2°. The attraction of its caloric by these molecules. 3°. The attraction of the molecule itself, either by the caloric of these molecules or by the molecules themselves. The caloric of each particle is supposed to be attached to it by the attraction of the particle. In aeriform bodies, the two latter, the attractive forces, are considered to be insensible, and the only action the molecules are subject to is that arising from the mutual repulsion of their caloric. This action is conceived to be independent of the nature of the molecules. From these principles Laplace derives, by no very complex mathematical reasoning, the fundamental properties of elastic fluids, viz., the law of Mariotte, the law of Dalton and Gay-Lussac, (which are shown to be true of mixed as well as simple gases,) and the law of the pressure of mixed gases. The same principles, together with the consideration of sensible and

latent heat and of specific heats, are employed in solving the problem of the velocity of sound, the solution of which, as was before remarked, Poisson has derived from the fundamental properties of elastic fluids considered as data of observation.

With reference to the preceding theory it may be remarked, that although it conducts by simple analysis to the fundamental properties of elastic fluids, and would seem on that account to possess the character of truth, yet it does not appear to have been very generally received, and by some is considered to be not sufficiently *natural*. I will venture to suggest a reason for this, which is equally applicable to some other of the more abstract physical theories, viz. that after we have gone through the mathematical reasoning, and been satisfied of its correctness, on recurring to the original hypotheses, there is some difficulty in judging of them or comprehending them by comparison with anything we see or know by experience. They are too little analogous to facts of observation. If a theory cannot rest on experimental facts, it ought at least to contain no hypotheses which may not be distinctly understood from our experimental knowledge: possibly it is not otherwise a view of the real facts of nature. In short, the evidence for the truth of hypotheses which from their nature do not admit of immediate verification by experiment, must depend as much on the facility with which they are conceived in the mind, and can be expressed in terms of acknowledged import, as upon the accordance of the mathematical results they lead to with experience.

In one* of the volumes of the Journal of the Polytechnic School there is an elaborate memoir by M. Poisson, which comprises the substance of two preceding memoirs on the equilibrium and motion of elastic bodies, and on the equilibrium of fluids, and concludes with calculating, according to the principles of the reasoning contained in the preceding part, the pressure of fluids in motion. Throughout this work the reasoning is conducted on the hypothesis that bodies are formed of disjoined molecules, separated from one another by spaces void of ponderable matter, which is considered to be "actually the case in nature;" and the chief object in view is to form the general equations of the equilibrium and motion both of elastic bodies and of liquid and aeriform bodies, according to this hypothesis, in a manner as simple and as free from difficulty as possible. By taking account of the void spaces separating the atoms, it is found that the pressure is expressed, not by an integral, but by a sum, which, on the supposition that the intervals between the molecules are small compared to their

* Tom. xiii. cah. 20, p. 1.

radius of activity, is reducible to a very converging series, the terms of which depend on the density. In this manner the following equation, containing two terms of the series, and applicable to solids not crystallized, to liquids, and to gases, is obtained:

$$p = a\,\rho^2 + b\,\rho^{\frac{2}{3}},$$

in which p is the pressure, equal in all directions, ρ the density, and a and b constant coefficients depending only on the nature of the body and the quantity of heat. This equation applies without any consideration of latent heat. Laplace in his speculations arrived at an equation of the form $p = a\,\rho^2$. But as it appeared from the phænomenon of the propagation of sound that for a given quantity of caloric, and consequently a constant value of a, the pressure varied nearly as $\rho^{\frac{4}{3}}$, to account for this difference the supposition of latent heat was introduced, which is avoided by the more general formula consisting of two terms. M. Poisson shows how his formula indicates that in solids and liquids the mutual attraction of the molecules extends further than their repulsion, and may be sensible at distances where the latter has altogether disappeared. In this and other of his writings M. Poisson considers the characteristic property of fluids, or the condition of fluidity to be, that the molecules arrange themselves alike in all directions from any fixed point, and with this property, that of pressing equally in all directions to be intimately connected. Probably few will be disposed to dissent from this view. But when he proceeds to assign as an *à priori* reason for this property the perfect mobility of the particles, and considers this mobility to result from their spherical form, or from their being so remote from each other that their form has no sensible influence on their mutual action, we cannot but feel that the cause assigned is not such that we can judge of it by any previous knowledge or experience. It would be more in conformity with the rule Newton laid down of referring effects to ultimate *mechanical* causes, if the mobility of the particles of fluids and the property of similar distribution in all directions about a given point, were ascribed to a particular action of the molecular forces resulting from a particular law of variation. If, for instance, the molecular repulsion from a single particle, or rather the resultant of the repulsions from an aggregate of particles, decreased very rapidly at a certain small distance from the centre to which it is directed, and then after becoming attractive, extended to a much larger distance without ever becoming of large magnitude, it seems demonstrable that

from such a law the above-mentioned properties would result; for the state of things would thus be nearly the same as if the fluid were supposed to consist of perfectly smooth spherical balls in contact, whose radii are all equal to the radius of the sphere of activity of the molecular repulsion, and whose centres consequently in the state of equilibrium are equidistant. This mode of accounting for the characteristic property of fluids is not inconsistent with the principal inference M. Poisson draws from his calculation of the pressure of fluid in motion, viz., that the pressure is not the same in all directions from a given point. For this deviation from the law of equal pressure may be reasonably ascribed to the circumstance that the molecules take *time* to fulfil the condition of similarity of arrangement, being made to assume their positions relatively to each other by the action of the repulsive and attractive forces. I may here observe that although the inequality of pressure of fluids in motion is a legitimate deduction from the molecular hypothesis, yet as theory cannot determine the amount of error committed by considering the pressure equal, it seems unnecessary to take account of the inequality unless some error should be detected by experiment, especially as we know beforehand that the amount must be very small.

In closing this communication, I beg leave to add a few notices respecting subjects contained in my former reports; and first, with regard to capillary attraction, it will be right to observe that some remarks made in the last report, in accordance with the strictures of Dr. Young on the equation in art. 12 of Laplace's Theory, I afterwards saw reason to conclude were incorrect, and in a communication to the *Philosophical Magazine and Journal of Science* for February 1836, explained that the proper inference from that equation, though Laplace omits to draw it, is, that the angle of actual contact of two fluids, or of a solid and fluid when the specific gravities are not very different, is an exceedingly small angle*, if the contact be perfect. It does not appear that any exception can be taken to the reasoning in any part of Laplace's Theory. The principles may indeed be objected to on the ground that Poisson takes up, viz., that if the molecular constitution of bodies be admitted, there must be a superficial variation of density which that theory takes no account of: as, however, experiment has not yet detected any such variation, and we have no means of assigning the amount of its

* A phænomenon I chanced to observe presented by oil floating on water seems to favour this inference. See *Phil. Mag. and Journal of Science* for April 1836.

influence, it would be premature to reject the theory on that ground, especially as the probability is that the effect which this consideration has on the numerical results of the calculations will at all events be small. In the paper just referred to I have given reasons for thinking that the law of molecular forces which will account for the fluidity of liquids is also that for which the effect of the superficial variation of density would be small in capillary phænomena.

Subsequent to the experiments by M. Link, which are noticed in the report on capillary attraction, others* were made by the same author not agreeing in their results with the former. After taking the precaution of freeing the solid plates against which the fluid ascended from the effects of greasiness contracted in polishing, it was not found as before, that different fluids ascended to the same height between the same plates; and the experiments only partially confirmed the law to which theory leads, of equal ascents of the same fluid between plates of different material thoroughly moistened. The deviation from this law is probably owing to the influence of particular affinities between the solids and fluids which the theory cannot take into account.

More recently have appeared the results of experiments by M. Frankenheim of Breslau, on the ascents of a great variety of fluids in capillary glass tubes†. These were made for determining the cohesion, or as M. Frankenheim calls it, the *synaphia* of fluid bodies. If h be the height of ascent, and r the radius of the tube, the specific synaphia he considers to be proportional to $\sqrt{r\left(h + \frac{r}{3}\right)}$. It is worthy of remark that the height of ascent of water in these experiments exceeds that of any of the other fluids, and that the mixing of water with other fluids has a very sensible effect in increasing their heights of ascent. It also appears that an increase of temperature sensibly diminishes the height of the ascending column. Similar experiments made some years since‡ by Mr. Emmett, assigned the highest ascent (except in one instance) to water, and clearly showed also the effect of an increase of temperature in diminishing the height. Mr. Emmett has made the remark that to produce this diminution of height it is necessary merely to increase the temperature of the *upper surface* of the fluid column.

* *Annalen der Physik und Chemie*, 1834, No. 38.
† *Annalen der Phys. und Chem.*, 1836, No. 2, p. 409.
‡ *Phil. Mag. and Annals*, vol. i. 1827, p. 115 and 332.

The circumstance of floating bodies rising vertically when drawn with considerable velocities along the surface of water, having attracted attention a few years ago, induced me to try to explain the fact on mechanical principles, and accordingly, in a paper published in the *Cambridge Philosophical Transactions**, I have entered on a mathematical investigation which accounts for such a fact, and shows in the instance taken, that when the velocity of draught is uniform the rise is proportional to the square of the velocity, in accordance with an experimental result obtained by Mr. Russell†. The inquiry is not pursued further in that paper (though I believe it may be done according to the method there employed), the immediate object in view being to gain confidence for the particular process of reasoning adopted, which differs in some respects from that of previous writers on fluid motion, by explaining to a considerable extent a fact which had not before been shown to depend on received mechanical principles.

The problem of the resistance of the air to a ball pendulum has been undertaken by M. Plana in a Memoir on the Motion of a Pendulum in a resisting medium, (*Turin*, 1835,) in which the resistance of an incompressible fluid is first considered, and then that of an elastic fluid; and in both cases the author finds, as Poisson had done, that the loss of weight of the sphere exceeds by just one half, the weight of the fluid it displaces. The question, however, has not yet received a satisfactory solution, since theory has hitherto failed to account for one of the leading circumstances of the case, viz., that the coefficient of resistance is different for small spheres of different diameters. This difference it appears would equally exist whether the balls vibrated in a confined apparatus or in free air.

The above particulars are mentioned for the purpose of calling attention to parts of the theory of fluids which are still open to improvement, and I may here state that one of the objects I have chiefly had in view in this communication to the Association, and in those preceding it, has been to bring into more notice the mathematical theory of fluids and place it in its proper rank among applied sciences. Judging from the very few contributions which have been made by Englishmen to this department of science, it would appear to have been held by us in disesteem. From the time of Newton till within these few years scarcely anything was written upon it in this country. This neglect is the less to be defended as there are few subjects in natural philosophy which are not connected in some manner or other with

* Vol. v. Part ii. p. 173.

† *Fourth Report of the British Association*, p. 533.

the properties of fluids. It is even possible that the present inquiries respecting the nature of the imponderable agents, which have given rise to such long-continued and widely extended experiments, may be waiting to receive satisfactory answers until greater perfection shall be given to the application of mathematics to the determination of the laws of fluid motion and pressure.

Comparative View of the more remarkable Plants which characterize the Neighbourhood of Dublin, the Neighbourhood of Edinburgh, and the South-west of Scotland, &c.; drawn up for the British Association, by J. T. MACKAY, *M.R.I.A., A.L.S., &c., assisted by* ROBERT GRAHAM, *Esq., M.D., Professor of Botany in the University of Edinburgh. Read at the Bristol Meeting, August* 1836.

CONTRACTIONS.—N. & S., North and South of Ireland. S. of I., South of Ireland. W. of I., West of ditto. S. N. & W., South, North, and West of ditto. S. & W., South and West of ditto. S. & N. of I., South and North of ditto. N. & W., North and West of ditto. S. Arran, South Arran. S. W. of I., South-west of Ireland. N. of I., North of ditto.

	Dublin.	Edinburgh.	South-west of Scotland.
Ranunculaceæ.			
Thalictrum minus	*	*	*
„ flavum	*	*	
Ranunculus parviflorus	*		
„ hirsutus	N. & S.	*	
„ arvensis...........		*	
Aquilegia vulgaris	*	*Naturalized as it probably is near Dublin.	
Trollius europæus		*	
Papaveraceæ.			
Papaper somniferum	*		
„ hybridum	*		
„ Argemone	*	*	
Meconopsis cambrica	*	*Introduced.	
Glaucium luteum	*	*	*
Fumariaceæ.			
Corydalis claviculata	*	*	
Fumaria parviflora,	S. of I.	*	
„ densiflora, D.C. ?		*	
Cruciferæ.			
Nasturtium sylvestre	*	*	
„ terrestre	*	*	
Alyssum calycinum† ...		*	

	Dublin.	Edinburgh.	South-west of Scotland.
Barbarea præcox	*	*	
Arabis ciliata,	W. of I.		
„ hirsuta	*	*	
Cardamine Amara	*	*	*
Thlaspi arvense	*	*	
Sisymbrium Iris	*		
„ Sophia	*	*	
Coronopus Ruelli	*	*	*
Lepidium ruderale	*	*Introduced.	
„ campestre	*	*	*
„ Smithii	*	*	*
Brassica monensis		....	*
Crambe maritima	*	*	*
Teesdalia nudicaulis		....	*
Raphanus maritimus ...		....	*
Violaceæ.			
Viola hirta	*	*	
„ odorata	*	*	
„ palustris	*	*	
„ flavicornis		*	
„ Curtisii	*		
Cistineæ.			
Helianthemum vulgare,	S. Arran	*	*

† This now appears to be the same plant which was published in my Catalogue of Irish Plants under the name of *Clypeola Ionthlaspi*, but as it is a doubtful native and has probably been introduced, I have for the present expunged it from the Irish Flora.

	Dublin.	Edinburgh.	South-west of Scotland.
Droseraceæ.			
Drosera longifolia,	N.&S.	....	*
„ anglica,	S.N. & W.	*	*
Malvaceæ.			
Malva rotundifolia	*	*	
„ moschata	*	*Introduced.	*
Althæa officinalis	S.&W.	....	*
Lavatera arborea	*	*	*
Hypericineæ.			
Hypericum Androsæmum	*	....	*
„ dubium	*		
„ hirsutum	*	*	
„ elodes	*	....	*
„ montanum		....	*
Caryophylleæ.			
Dianthus Armeria		*	
„ deltoides, lately found near Cork		*	*
Saponaria officinalis	*	*Introduced.	
Silene anglica,	S. & N. of I.	*	*
„ conica		*	
„ nutans		*	
„ noctiflora		*	
Lychnis dioica α & β	*	*	*
„ viscaria		*	
Sagina maritima	*	*	*
Arenaria ciliata	N. & W.		
„ verna	N. & S.	*	
Cerastium arvense	*	*	
Stellaria glauca	*	*	
Lineæ.			
Linum angustifolium	*		
Geraniaceæ.			
Geranium sanguineum	*	*	*
„ sylvaticum		*	
„ pratense		*	
„ pyrenaicum	*	*	
„ lucidum	*	*	
„ pusillum		*	
„ columbinum	*	*	
Erodium moschatum	*		
„ maritimum	*	....	*
Crassulaceæ.			
Cotyledon umbilicus	*	....	*
Sedum villosum		*	
„ reflexum	*	*	
„ rupestre	*	....	*
„ Telephum		*	*
Radiola rosea		....	*
Saxifrageæ.			
Saxifraga Hirculus		*	
„ granulata	*	*	
„ tridactylites	*	*	
„ hyperoides		*	*
„ aizoides		....	*
Leguminosæ.			
Ulex nanus	*	....	*
Genista tinctoria	*	*	*
Ononis reclinata		....	*
Astragalus glycyphyllus		*	
„ hypoglottis	S. Arran	*	*
Vicia lutea		*	*
Genista anglica		*	
Orobus sylvaticus		*	
Melilotus officinalis	*	*	
„ leucantha	S. of I.	*	
Trifolium ornithopodioides	*	*	*
„ maritimum	*		
„ scabrum	*	*	
„ striatum		*	
„ fragiferum	*	*	
Oxytropis uralensis		*	*
Lotus tenuis		*	
Medicago maculata		*	
Rosaceæ.			
Spiræa Filipendula		*	
Rubus saxatilis		*	*
„ Chamæmarus		*	
Potentilla fruticosa	S. W. of I.	*	
„ argentea	*	*	
„ verna		*	
Rosa tomentosa	*	*	
„ micrantha	*		
„ arvensis	*	*	
Pyrus pinnatifida		....	*
Tormentilla reptans		....	*
Onagrariæ.			
Epilobium angustifolium	*	*	

Dublin.	Edinburgh.	South-west of Scotland.
Umbelliferæ.		
Crithmum maritimum *	....	*
Silaus pratensis N. of I.	*	
Œnanthe pimpinelloides *	*	*
„ Phellandrium *	*	
Helosciadium repens...	*	
Pimpinella magna S. of I.		
Carum verticillatum N. & S.	....	*
Apium graveolens *	*	*
Ligusticum scoticum...	*	*
Stellatæ.		
Galium Mollugo *	*	
„ pusillum S. & W.	*	
Asperula Cynanchica, S. & W.		
Rubia peregrina *		
Caprifoliaceæ.		
Linnæa borealis.........	*	
Campanulaceæ.		
Campanula rapunculoides	*	
„ latifolia, Mid. C.	*	
„ glomerata	*	
„ Trachelium *	* Perhaps introduced.	
„ hederacea *	....	*
„ hybrida	*	
Jasione montana *	....	*
Valerianeæ.		
Fedia dentata *	*	*
„ auricula, W. of I. Bab.	*	
Valeriana rubra *		
Compositæ.		
Limbarda crithmoides *	....	*
Erigeron acris *	*	*
Artemisia gallica	*	*
„ maritima *	*	*
Carduus nutans, N. & W.	*	
„ tenuiflorus *	*	*
„ marianus *	*	
Crepis biennis *		
Helminthia echioides *	....	*
Picris hieracioides, *rare**		

Dublin.	Edinburgh.	South-west of Scotland.
Hypochæris glabra......	*	*
Tragopogon pratensis *	*	
„ major...............	*	
Lactuca virosa	*	
Boragineæ.		
Lithospermum maritimum *	*	*
„ officinale *	*	
Symphytum officinale*	*	*
Cynoglossum officinale*	*	*
Asperugo procumbens..	*	
Convolvulaceæ.		
Convolvulus soldanella*	....	*
Polemoniaceæ.		
Polemonium cœruleum*	*Introduced.	
Plumbagineæ.		
Statice Limonium *	....	*
„ spathulata *	....	*
Ericeæ.		
Andromeda polifolia *	....	*
Menziesia polifolia, W. of I.		
Erica mediterranea, W. of I.		
„ Mackaiana, W. of I.		
Arbutus Unedo, S. of I.		
Pyrolaceæ.		
Pyrola media, Down & Derry	*	
„ minor, Northern Counties and Mayo	*	
„ secunda, Derry and Antrim...	*	
Monotropa hypopitys *		
Gentianeæ.		
Exacum filiforme, Kerry		
Gentiana verna, W. of I.		
Chlora perfoliata *		
Solaneæ.		
Solanum Dulcamara *	*	
„ nigrum	....	* Probably introduced.

	Dublin.	Edinburgh.	South-west of Scotland.
Primulaceæ.			
Primula elatior	*	*	
„ veris	*	*	
„ farinosa		*	
Centunculus minimus, N. & S. of I.		....	*
Lysimachia thyrsiflora		*	
Hottonia palustris, near Downpatrick			
Trientalis europæa		*	
Lentibulariæ.			
Pinguicula grandiflora, S. of I.			
„ lusitanica	*	....	*
Scrophularineæ.			
Veronica Buxbaumii		*	*
Bartsia viscosa, S. of I.		....	*
Sibthorpia europæa, S. of I.			
Limosella aquatica		*	
Scrophularia vernalis		*Naturalized	
Orobancheæ.			
Orobanche minor	*		
„ rubra, N. of I.		*	
Lathræa squamaria, S. of I.		*	*
Verbenaceæ.			
Verbena officinalis	*		
Labiatæ.			
Salvia verbenaca	*	*	
Mentha gentilis		*	
Galeobdolon luteum	*		
Betonica officinalis		*	*
Nepeta cataria	*	*	*
Galeopsis Ladanum	*	*	
„ versicolor		*	*
Thymus Calamintha	*		
Origanum vulgare	*	*	
Lamium intermedium		*	
Acinos vulgaris		*	
Polygoneæ.			
Polygonum Raii	*	....	*
„ viviparum		*	
Chenopodeæ.			
Chenopodium olidum	*	*	
Atriplex portulacoides	*	....	*
Resedaceæ.			
Reseda lutea	*	*	
“ fruticulosa	*		
Euphorbiaceæ.			
Euphorbia hiberna, S. & N. of I.			
„ paralia	*	....	*
„ Portlandica	*	....	*
„ Ezula		*	
„ amygdaloides, S. of I.			
Mercurialis annua	*	*	
Coniferæ.			
Taxus baccata, var. fructu flavo, lately observed near Dublin in cultivation.			
Aroideæ.			
Arum maculatum	*	*	
Acorus calamus		....	*
Typhaceæ.			
Typha angustifolia		* Probably introduced.	
„ β minor	*		
Alismaceæ.			
Alisma natans	*	....	*
Orchideæ.			
Orchis pyramidalis	*	*	*
Gymnadenia conopsea	*	*	
Habenaria Chlorantha	*	*	
„ bifolia		*	
Ophrys apifera	*		
Neottia spiralis	*		
Corallorhiza innata		*	*
Listera cordata	*	*	*
„ nidus-avis		*	*
Epipactis palustris	*	*	
„ latifolia	*	*	*
„ ensifolia		....	*
Malaxis paludosa	*	*	*
Amaryllideæ.			
Narcissus biflorus	*	*Introduced.	
Asphodeleæ.			
Allium arenarium	*	*	

	Dublin.	Edinburgh.	South-west of Scotland.
Allium carinatum	*		
Scilla verna	*		*
Smilaceæ.			
Paris quadrifolia		*	
Butomeæ.			
Butomus umbellatus	*	*Introduced.	
Junceæ.			
Juncus acutus	*		
„ maritimus	*	....	*
Gramineæ.			
Calamagrostis epigejos.		....	*
Avena planiculmis......		....	*
Hordeum maritimum	*	*	
„ pratense	*	*	
Triticum loliaceum	*	*	*
Rottbollia filiformis	*	*	
Cyperaceæ.			
Rynchospora fusca,	S. & W.		
Blysmus rufus	*	*	
„ compressus		*	
Schœnus nigricans	*	*	*
Scirpus Savii	*	....	*
Eriophorum pubescens	*		
Cladium mariscus,	S. & W.	....	* John Mackay.
Carex curta,	N. & S.	*	
„ axillaris	*	*	
„ strigosa	*	*	

	Dublin.	Edinburgh.	South-west of Scotland.
Carex extensa	*	*	*
„ distans	*	*	*
„ limosa	N.	*	*
„ filiformis		*	
Filices.			
Polypodium vulgare *var.*	*		
Aspidium angulare	*	....	*
„ lobatum	*	*	
Asplenium marinum	*	*	*
„ septentrionale ...		*	
„ viride...............		*	
„ alternifolium......		*	
Cryptogramma crispa...		....	*
Trichomanes brevisetum,* rare; more plentiful at Killarney.			
Hymenophyllum Wilsoni	*	*	*
„ Tunbridgense	*		
Ophioglossum vulgatum		*	
Lycopodiaceæ.			
Lycopodium inundatum		....	*
Marsileaceæ.			
Isoetes lacustris	*		
Pilularia globulifera....		*	
Equisetaceæ.			
Equisetum variegatum	*	*	
„ Drummondii		*	

Comparative geographical notices of the more remarkable Plants which characterize Scotland and Ireland. Read at the Bristol Meeting of the British Association, August, 1836. *By* J. T. MACKAY, *M.R.I.A., A.L.S., &c.*

ALTHOUGH the Flora of Ireland cannot boast of so great a number of species as the neighbouring island, still there are several very remarkable circumstances which attract our attention when we contrast the vegetation of Ireland with that of Great Britain.

If, in the first place, we compare the vegetation of Ireland with that of Scotland, we find that climate has exercised a powerful influence. Ireland is situated more to the south than Scotland, and its mountains are not so high; it is also more exposed to the Western Ocean, hence its climate is more characterized by moisture: Scotland is therefore much more rich in Alpine plants than Ireland, as the following list of those found in Scotland and not in Ireland will show. On the other hand the mildness of the Irish climate is perhaps the cause why plants are found on the western coast whose relative habitats are the mountains of Spain and Portugal. It is, however, difficult to account for the localities of a few plants as they occur in Ireland. Thus *Helianthemum vulgare*, so common in Scotland and England, although one of the first plants that presents itself to our view on the rocks about Portpatrick, has not yet been found in Ireland unless in the Island of Arran on the western coast; and *Astragalus hypoglottis*, so common about Edinburgh and elsewhere in Scotland, is in Ireland confined to the same locality.

It may also not be unworthy of remark, that *Arenaria verna*, which grows on the basaltic rocks of Arthur's Seat, is found on the same kind of rock at Magillegan, County of Derry. I have, however, specimens of the same plant from the west coast of Clare, where the rocks are, as far as I have observed, composed of limestone.

List of some of the more remarkable Alpine and other plants of Scotland which are not found in Ireland:

Veronica alpina
„ saxatilis
Eriophorum capitatum
Alopecurus alpinus
Phleum alpinum
„ Michelii
Aira alpina
Hierochloe borealis
Avena planiculmis
Poa laxa
Cornus suecica
Myosotis alpestris
Primula scotica
„ farinosa
Azalea procumbens
Gentiana nivalis
Sibbaldia procumbens
Meum Athamanticum
Juncus balticus
Juncus filiformis
„ biglumis
„ triglumis
„ trifidus
„ castaneus
„ tenuis
Luzula arcuata
„ spicata
Trientalis europæa
Menziesia cœrulea
Vaccinium uliginosum
Epilobium alpinum
„ alsinifolium
Polygonum viviparum
Pyrola uniflora
Arbutus alpina
Saxifraga nivalis
„ cernua
„ rivularis

Saxifraga pedatifida
Arenaria rubella
„ fastigiata
Cherleria sedoides
Lychnis alpina
„ viscaria
Cerastium alpinum
„ latifolium
Nuphar minima
Bartsia alpina
Linnæa borealis

Draba rupestris
Arabis petræa
Sonchus alpinus
Hieracium alpinum
„ Halleri
Erigeron alpinum
Astragalus alpinus
Oxytropis campestris
„ Uralensis
Ononis reclinata

Geographical notices of several plants found in Ireland, most of which have not yet been found in England or Scotland:

Pinguicula grandiflora, South of Ireland, South of France.
Erica mediterranea, West of Ireland, Western Pyrenees. *E. Mackaii*, Hooker in *Companion to Botanical Magazine*.
„ *Mackiana, Bab.* West of Ireland, Spain.
Arbutus unedo, South of Ireland, South of Europe.
Menziesia polifolia, West of Ireland, Spain, Pyrenees and Portugal.
Arenaria ciliata, Sligo Mountains, Swiss Alps.
Saxifraga Geum, South of Ireland, Western Pyrenees.
„ *hirsuta*, South of Ireland, Western Pyrenees.
„ *umbrosa*, 2 varieties, South, West and North of Ireland, Pyrenees.
„ *elegans, Fl. Hib.*, South of Ireland, rare.
„ *affinis, Fl. Hib.*, South of Ireland.
„ *hirta, Fl. Hib.*, South of Ireland.
Rosa Hibernica, North of Ireland.
Arabis ciliata, West of Ireland, Switzerland.
Hypericum calycinum, South of Ireland near Killarney, and coast of Clare, in hedges; South of Europe.
Ulex strictus, (which is probably only a variety of *U. europæus*,) North of Ireland, sparingly.
Neottia gemmipara, South of Ireland, *rare*, Drummond.
Taxus baccata, var. *hibernica*, (*Taxus fastigiata*, Lindley,) North of Ireland and Florencecourt, cultivated.
Carex Buxbaumii, North of Ireland, North of Europe, North America.
Eriocaulon septangulare, West coast of Ireland, Island of Sky, Scotland.
Trichomanes brevisetum. Found in several places near Killarney in considerable abundance, and very sparingly in the County of Wicklow. I have specimens of this Fern collected in Madeira by the late Doctor Shuter.

Report of the London Sub-Committee of the British Association Medical Section, on the Motions and Sounds of the Heart.

The Committee of Members of the British Association resident in London who have been charged with the investigation of the motions and causes of the sounds of the heart, have held numerous meetings, and performed a considerable variety of experiments, on living and on dead subjects, with a view to the ends of their appointment. They have also taken pains to inform themselves of the facts and reasonings published by preceding inquirers, and have now the honour to submit to the Section the results at which they have hitherto arrived, together with such particulars of their experiments as they consider necessary to substantiate their conclusions.

Before entering, however, upon the statement of their experiments or of the conclusions to which they lead, they beg leave to say a few words with regard to the scope and plan of their inquiries, and the spirit in which they have entered on them. The Committee would first remark, that though in their inquiries they did not neglect to take note of any phænomena which might illustrate the action of the diseased heart, yet they have felt it their especial duty to investigate the physiological branch of the subject, and have principally occupied themselves with that part which includes the normal sounds of the heart. In thus limiting the field of research, it will be sufficient perhaps to remind the Section that they have pretty closely followed the example of the Dublin Committee of last year.

With regard to the spirit and general views by which they have been guided they wish to observe, that in entering upon the investigation it seemed to them possible *à priori* that each sound of the heart might have a single peculiar cause, or several co-operating causes; and if several co-operating causes should be found more probable, that then some of such causes might be only contingent or occasional, and others constant and invariably present; also, upon the supposition of a plurality of causes of one or both sounds, that some causes might be common to both sounds, or that each sound might have its own set of causes exclusively. Keeping in view those several possible *à priori* positions, the Committee made an enumeration of the circumstances attending the heart's action that had been, or might be, supposed capable of producing sound, and endeavoured so to vary their experiments as to exclude in turn each of those circumstances, with a view

to isolate or at least to bring sufficiently into relief the essential cause or causes of each sound. To the execution of the plan of experimental inquiry thus glanced at, the Committee have devoted some time during the summer, in the course of which they have had to encounter numerous difficulties, especially from the want of sure means of destroying the sensibility of the animal, without suspending or greatly impairing the action of the heart. And in this respect they have been much less fortunate than several preceding experimentalists, having in no one of the numerous subjects on which they have operated, been able to continue their observations for a longer period than forty-five minutes, notwithstanding the utmost care to avoid unnecessary loss of blood and to maintain artificial respiration. It is proper to add, that the subjects of these observations were in most instances young asses from three to six months old, in apparently good health, and that the mode of preparation was in a few instances poisoning with woorara, in others stunning by a blow on the head, but in a majority of the experiments the animal was pithed. Other animals were tried as well as young asses, viz. the horse, the dog, and the domestic fowl; but for various reasons these trials were not attended with results recommending their repetition.

The Committee consider the most convenient order in which to state the facts in their possession, and their inferences from those facts, to be, to describe first succinctly, and from the original notes taken on the spot, such of their experiments as gave available results; then briefly to arrange, under the head of each supposed or possible cause, such points in the experiments as may seem to the Committee to make decidedly in favour of or against the claims of each of such possible causes; and lastly, to give a summary of the conclusions which the Committee have adopted from the whole of their inquiries.

Memoranda of Experiments, &c.—The Committee made some observations in the first instance on their own persons. To satisfy themselves fully as to how far the sounds might be modified by circumstances, such as the state of the lungs, whether distended or collapsed; the state of the circulation, whether excited or tranquil; and the position of the body; the Committee examined the heart in their own persons under all those varieties of circumstance, and found, that when the subject of observation is supine or leaning a little backwards towards the right side, the first sound is uniform, dull, and without any easily perceptible impulse; but the subject leaning forwards, and especially if inclining much to the left side, the

first sound is louder and fuller-toned, and accompanied by strong impulse. They found also that full inspiration operated like leaning to the right, or the supine position, by diminishing sound and impulse, while full expiration like leaning forwards, or to the left side, rendered the sounds and impulse more distinct, the former louder, the latter stronger and more diffused. When the heart's action is excited by exertion they found, as might be anticipated, the systolic sound and impulse at their maximum of tone and force. Moderate exertion they observed to increase the intensity of both sounds; whereas sudden exertion, sufficiently violent greatly to accelerate the action of the heart, they found impaired the distinctness of the second sound, the first continuing loud, short, and with strong impulse.

The indistinctness of the second sound in rapid pulsation of the heart, seemed to depend in part on its following so closely on the loud first sound as to be masked by it.

Experiment 2.—The Committee made experiments likewise on muscular contraction in their own persons, with a view to ascertain how far that act is accompanied by sound. The muscles operated on with the best effect were the buccinator and masseter, the muscles of the neck and fore-arm, and of the parietes of the abdomen. In all those the flexible ear-tube, carefully applied so as to prevent friction, yielded sounds more or less striking; but the most striking results were obtained from the last-mentioned parts. From the abdominal muscular contractions, sounds of a "systolic" character (if the expression is admissible) in all respects, and as loud or louder than those of the heart, were with facility obtained: the sounds were excited by sudden expiratory efforts made with force, and with the mouth closed, and were obtained from various parts of the parietes. The sound of muscular contraction seems in the case of the abdominal muscles to be exaggerated by the hollowness of the subjacent parts.

At the time the sound was heard the muscle under observation always felt to the finger tense and hard, but the loud sound ceased at the moment that the fibres had attained their maximum of tightness and hardness, and was not renewed except by a repetition of the contractile effort after previous relaxation.

Experiment 3.—Subject, a young ass poisoned with woorara introduced into an incision in the flank.

The animal died sixteen minutes after the introduction of the woorara; much blood was lost in opening the chest; the heart was acting at the moment of exposure, but not strongly. Its action became more regular after inflation was made more regularly.

Both sounds were heard with the instrument applied to the great arteries; but the sound with impulse or first sound alone was heard on the ventricles.

The heart could not, the Committee were satisfied, strike against the chest's walls, or any other hard object.

After opening the pericardium the sounds were weaker; but both sounds were heard with the stethescope applied to the roots of the great arteries. Both sounds were heard also on the great arteries where a portion of lung was interposed between the instrument and the vessels.

The heart continued to act for forty minutes.

Experiment 4.—Subject, a young ass prepared as the last. Death twenty-six minutes after poisoning.

At the roots of the great arteries the two sounds were distinctly heard, but after the introduction of two curved awls into the arteries (for the purpose of hooking up one lamina of each sigmoid valve) the second sound was wanting, the first being still distinct; on withdrawing the awls two sounds were heard, and soon after the heart ceased to act, twenty minutes after the death of the animal. At each systole while the heart acted vigorously, the ventricles felt to the finger as hard as cartilage.

The heart being cut out and plunged in warm salt and water, a slight undulatory contractile motion pervaded the substance of the ventricles and columnæ carneæ and continued for some time. In this and every other observation the vermicular or undulatory motion supervened upon the cessation of the normal action of the organ, and never before the organ had ceased to act as a whole.

Experiment 5.—Subject, a donkey seven months old, which expired forty-three minutes after being poisoned with woorara.

The heart just before death was heard with short loud pulsations; when the chest was opened, it ceased to beat, and was very much distended with blood. When part of the blood was let out by cutting the pulmonary artery, the ventricles began again to pulsate feebly, but without sound. When the heart was cut out it presented the undulatory motion, which was increased by immersion in cold water. The two ventricles being opened by cuts at the apex at right angles to the septum, and the heart being drawn with the apex upwards through water, the laminæ of the mitral and tricuspid valves were seen to close together each time the heart was so drawn upwards through the water.

Experiment 6.—Subject, a young ass destroyed by pithing.

On opening the chest the heart acted regularly, producing both sounds distinctly: curved awls were then introduced into

the aorta and pulmonary artery to hook back the valves, when the second sound was replaced by a sucking or bellows sound. The awls being withdrawn both sounds were again heard, the heart acting feebly.

Experiment 7.—Subject, a young ass. A small quantity of woorara was introduced into the flank, but without destroying life, and the animal was despatched by a blow on the head.

Heart acting very quickly and strongly when the chest was opened; first sound only audible.

The auricles being pushed in by the fingers into the ventricles so as to keep the valves open, the first or impulse sound only heard; the second sound wanting. On withdrawing the fingers from the auricles both sounds were audible, the heart acting more slowly but yet strongly. The roots of the arteries being compressed between the fingers and stethescope, the first or impulse sound only heard, accompanied by a loud bellows or rasp sound. On removing the pressure (from the arteries) both sounds again audible. An incision being then made into the left auricle, a finger was passed through the auriculo-ventricular orificeto the bottom of the left ventricle, and the fingers of the other hand being placed under the right ventricle, and the heart compressed between the hands so as to obliterate the cavity, the first or impulse sound was still distinctly heard by all, but weak.

Experiment 8.—Animal, a young ass destroyed by stunning. The heart at first acted convulsively, as from great exertion, but afterwards nearly normally slowly for a short time. While the heart's action was quick no second sound was heard, but after it became slow both sounds were heard, and shortly after its action became too feeble and irregular for observation.

Experiment 9.—Subject, a young ass. Poisoning by introduction of twenty-four drops of an inefficient preparation of coneia into the peritoneum: unsuccessful. Animal ultimately pithed. On opening the chest the heart distinctly audible as to both sounds, and in vigorous action. The fingers were pushed into the auricles and through the auriculo-ventricular orifices, when a first sound was heard prolonged by a whizzing sound.

On withdrawing the fingers both normal sounds were heard; needles were then introduced to hook up a lamina of the sigmoid valves of the aorta, when the second sound was heard by two observers.

The pulmonary sigmoids were also attempted to be so treated (the aorta valves being continued under the needle), when two observers heard the two sounds, but not the third observer.

Note.—The Committee were uncertain how far the hooking up of the valves was really effected owing to want of strength in

the needles. They were not afterwards able, as in other cases, where curved awls were used, to find the marks of the needles so as to ascertain the direction in which they had passed.

Experiment 10.—Subject, a young ass pithed. Chest immediately opened, when the heart was acting slowly, but forcibly. At first no second sound was heard, but a bellows sound (instead); then a violent action was attended with a single sound, accompanied by a bellows sound, which (latter) ceased as the heart became more slow in action, after which both sounds became distinct; then, the arteries being pressed with the fingers at their origins, a first sound was heard, with a blowing murmur accompanying and another (murmur) following, but no flapping (or second) sound. On removing the pressure (from the arteries) the second sound was heard and the murmur ceased. Immediately after the systole a flapping or jerking sensation was sensible to the finger applied to the arteries at their roots.

The inversion of the auricles was accompanied by a sensation of thrilling in the finger of the operator. The auriculo-ventricular valves were found to act in water after the removal of the heart from the body, closing on its being drawn apex upwards through water.

Experiment 11.—Subject, a young ass poisoned with oil of bitter almonds.

A small opening was made in the cartilages opposite the heart, when the stroke was perceived, and felt by the finger inside and outside the sternum at the same time, with sound, and with considerable pressure upwards against the finger placed between the heart and cartilages.

The chest and pericardium were then opened, which latter had a little serum in it. After turning over the animal on its left side, so as to make the heart hang vertically (out of the chest), a first sound was heard through the tube applied to the ventricles, but no second sound by either observer. The same sound was heard on the right auricle posteriorly without the second sound: the heart acted both times weakly. The tube being applied to the roots of the arteries gave the same result to one observer, *i. e.*, a first without a second sound. The animal being again laid on his right side the first sound was heard by two observers. Circumstances prevented the third member of the Committee from ausculting during this experiment, which was not repeated.

Experiment 12.—Subject as above, and pithed.

Heart acted thirty-three minutes. On opening the chest the two sounds were heard, the heart acting slowly and with tolerable force.

The auricles were then inverted by the fingers, and the first sound, continued into a bellows murmur, was heard. The mur-

mur was accompanied by a thrilling motion, sensible to the finger of the operator, and synchronous with the impulse. A lamina of each sigmoid valve was then hooked up (with dissecting hooks), when a sound was heard not followed by a second sound, but on removing the hooks the second sound was again heard.

On inverting the auricles again the chordæ tendineæ of the mitral valve alone were felt to become tense in systole and lax in diastole. A finger being introduced into the left ventricle through the auricle, the first sound was heard with a murmur.

Experiment 13.—Subject, a young ass, pithed. On opening the chest, and then the pericardium, both sounds were distinctly heard, but feeble. On touching the arteries in the vicinity of the valves, a sensation of flapping (or jerking) observed by all, commencing immediately after the systole, and accompanying the second sound.

The awls being introduced into the arteries (so as to hook up the valves), the second sound was wanting. After removing the awls, at first but the systolic sound was heard, but after a short time both were heard by all.

On opening the heart (at the close of the experiment), the valves were found to have been sufficiently hooked up in both arteries.

Experiment 14.—Subject, a young ass, pithed. After opening the chest the pericardium was opened, and a thick layer of tow was interposed between the heart and surrounding parts, the heart continuing to act. At first the systolic sound was heard, followed by a bellows murmur; but afterwards the flapping sensation and second sound very distinct also.

The finger being introduced into the left ventricle by inversion of the auricle, was felt to be gently embraced and pushed, as if by a membrane distended with blood. On the right side nothing similar unequivocally observed. On pressing the aorta or pulmonary artery between the finger and thumb gently, a "to and fro" thrill was felt accompanying the systole and diastole of the ventricles, and terminated by a flap. The sensation of flapping (or jerking) was felt to be synchronous in the two arteries.

The tension and hardness of the ventricles during their systole was very remarkable.

The pulmonary artery being cut across, the first sound was still loud, and the aorta being then cut across (likewise), the same result was obtained (viz. a first, without a second sound). The heart was then severed from its other attachments, and the (first) sound was still heard distinctly.

The heart was then grasped strongly under blood, and it continued to contract vigorously, and the first sound was heard (but not loud) with the flexible tube as well as the common stethescope. The heart was then taken out and held in the hand of one of the Committee, when the first sound was distinct, but feeble.

On opening the right ventricle the columneæ carneæ were distinctly seen contracting simultaneously with the ventricle.

Such are the particulars of all the more successful experiments of the Committee, with regard to those possible causes of the normal sounds of the heart which have been investigated by the Committee; the principal of them are as follows. The first sound has been attributed to

1. *Impulse,* or the beating of the heart against the parietes of the chest.

2. *Muscular sound,* or the resonance attending sudden muscular contraction.

3. *Collisions* of the particles of the blood amongst each other, or against the parietes, valves, &c. of the heart's cavities.

4. The *action* of the *auriculo-ventricular valves* during systole.

5. And the *collision* of the *opposite interior surfaces* of the *ventricles* in the same state.

The normal or second sound has been attributed to

1. *Impulse* of the heart *against* the *thoracic parietes,* owing to its rapid expansion during diastole.

2. *An intrinsic sound* attending the diastole, analogous to that which the observations of the Committee prove to attend the systolic action of the ventricles.

3. *Flapping of the auriculo-ventricular valves* during diastole against the sides of the ventricles.

4. The *rushing of fluids into the great arteries* after the systole.

5. The *rushing of the fluids from the auricles into the ventricles* during diastole.

6. *Sudden tension and flapping* of the *sigmoid valves* after the systole.

Of the causes to which the first sound has been attributed, the Committee feel it necessary to notice each separately, except the last. With regard to the alleged causes, however, of the second sound, they will feel themselves justified in being less minute, partly to avoid tiresome repetitions, but principally on account of the obvious preponderance of evidence, as the Committee conceive, in favour of the theory last mentioned.

First Sound—Valvular Tension.—To begin with the first

sound. It is well known that several eminent writers have attributed it to the sudden closure and tension of the auriculo-ventricular valves during the systole. With reference to that question, the Committee have made the following observations:

1. Inverting the auricles, and passing the finger into the auriculo-ventricular orifices, does not prevent the first sound, though it must prevent the action of the valves. Experiments 5, 8, &c.

2. In the experiments just referred to, the action of the mitral valve, as felt by the finger, was of too gradual and feeble a kind to be capable of producing sound; while on the right side the tightening of the tricuspid was not strong enough to be sensible to the finger at all.

3. Various instances where the ventricles were treated so as to obliterate their cavities by pressure, and render valvular action impossible, gave, nevertheless, the first sound. Experiments 6, 7, &c.

From these facts the Committee conclude that valvular action is not a cause of the first sound.

First Sound—Collision in the Fluids, &c.—The following are the facts observed by the Committee with regard to the alleged resonant collisions of the particles of blood amongst themselves, or against the parietes, valves, &c. of the ventricles.

1. The obstruction of the auriculo-ventricular orifices by the fingers introduced by inverting the auricles does not materially modify the first sound. Experiments 5, 8, &c.

2. The heart being pressed between a finger introduced through the auricle to the bottom of the left ventricle, and the other hand placed outside the right ventricle, continued still to emit the first sound. Experiments 5 and 12.

3. The heart being grasped firmly in the hand, after separation from its attachments, and while immersed in blood, gave the first sound distinctly. The pressure in this case must, in the opinion of the Committee, have prevented collision between the opposite interior surfaces of the organ.

4. The division of the aorta and pulmonary artery, and even the extraction of the heart, does not prevent the first sound. Experiment 12.

5. The Committee made also various experiments in order to ascertain the power of fluids to produce sound when in contact with solids.

On compressing by the stethescope the gum elastic bottle filled with water, and under water, they could not succeed in producing any other sound than a bellows sound. The power of obstructed currents of liquid to produce the various modifications of the bellows sound was further illustrated to the Com-

mittee in several experiments on animals, in which pressure of the arteries, partial obstruction of the auriculo-ventricular orifices, and suspension of the action of the sigmoid valves, were repeatedly accompanied by this phænomenon. The thrill accompanying this sonorous passage of liquid was in every case sensible to the finger.

6. To this we may add that the experiments of MM. Pigeaux and Piorry have been repeated by the *Reporter* in the presence and with the assistance of Dr. Edwin Harrison, and other gentlemen not of the Committee; but in no instance of several trials was anything like the first sound produced.

From the preceding facts the Committee conclude that the normal first sound of the heart is in no degree referable to any collisions of the particles of the fluids amongst themselves or against the parietes, &c. of the ventricles.

First Sound—Impulse.—The facts relating to the connexion of impulse with the first sound that are contained in the preceding experiments, are the following:

In a variety of circumstances in which it is difficult to see how impulse could occur to cause sound, the systolic sound was distinctly audible, viz.

1. When the heart lay exposed, deprived of its pericardium, and supported by the mediastinum alone, as in Experiment 1.

2. When the heart was held between the fingers with some force of pressure, the left side cavities being empty, or nearly so, as in Experiment 5.

3. When the heart was imbedded in tow. Experiment 14.

4. When the heart hung out of the thorax by its vessels, removed from all contact to which sound might be referred, as in Experiment 9.

Note. In the four experiments just referred to the instrument was applied to the arteries near their roots.

5. When the heart was severed from all its attachments, and grasped strongly in the hand, as in Experiment 12. On the other hand, several facts show that the impulse against the ribs may produce sound.

6. In Experiment 11, and in others in the memoranda of which the fact has been omitted, the heart during systole was felt, both outside and inside the chest, to press with force against the sternum and cartilages.

7. In our observations on the effects of posture we remarked that leaning to the left or forwards gave additional force to the impulse and loudness to the sound; while inclination of the body, such as to cause the heart to gravitate away from the ribs, diminished at once the sound and impulse.

8. To those we may add the facts pointed out by Dr. Spittal, which have been repeated and verified by the Reporter, assisted by Dr. Edwin Harrison and other gentlemen not of the Committee, and which seem to prove that if the living heart impinge with any force upon the walls of the thorax sound must result.

From the whole of those facts, the Committee conclude that impulse is not the principal cause of the first sound, but that it is an auxiliary and occasional cause, nearly null in quietude and in the supine posture, but increasing very considerably the sound of the systole in opposite circumstances.

First Sound—Muscular Tension.—The facts ascertained by the Committee relating directly to muscular tension as a possible cause of the first sound, are few but striking, and in their judgement decisive.

1. The heart in systole becomes suddenly, from a comparatively soft and flaccid body, extremely tense, and to the touch hard as cartilage. Experiments 2 and 12, and many others, in which the fact was not recorded.

2. The unvarying and uniform character of the systolic sound, however diversified the circumstances in which the heart was placed, furnishes a strong argument in favour of its intrinsic nature.

3. The voluntary muscles, when suddenly contracted, become tense and hard, and emit sounds resembling strikingly the first sound of the heart. This is especially observable in the action of the abdominal muscles. Experiment 14.

4. From those experimental facts, taken along with the self-evident fact, that the muscular tension thus experimentally proved to be sonorous is an essential part, and, as it were, the first stage of full muscular contraction, the Committee conclude that the first sound of the heart is, for the most part, a physical result of the sudden transition of the ventricles from a flaccid condition to a state of extreme tension; that in a word the first sound is essentially a muscular sound.

Second Normal Sound of the Heart.—We now proceed to the consideration of the normal second sound, and of the hypotheses that have been or might be advanced respecting it, and the facts we possess that throw light on its causes and mechanism.

The Committee had proceeded but a short way in their experimental inquiries when they found the conclusion forced on them that the majority of the hypotheses (above enumerated) regarding the second sound were wholly untenable. In some of their first experiments they found that the second sound might be absent, although the first sound was present, and the systolic

and diastolic actions were quite normal. The second sound, for example, was suppressed by

1. Pressure on the roots of the arteries.
2. By hooking up a valve of each set of sigmoids.
3. By suspending the heart out of the chest.
4. By inverting the auricles, &c. (see Exp. *passim*), the first sound and alternate ventricular actions continuing unaffected in any material degree in each case. Such facts, of which there are many in the account of the experiments, seemed to the Committee quite incompatible with any other hypothesis respecting the second sound than the last, viz. that which refers it to the action of the semilunar valves. Besides, several of those hypotheses appeared liable to the weighty preliminary objection that they are wholly arbitrary, and without any foundation, so far as the Committee have been able to ascertain, in accurate observations or experiments. Under those impressions the Committee think it best to proceed at once to state the facts which in their opinion tend to establish the action of the sigmoid valves to be the cause of the normal second sound. In this some repetition perhaps may be necessary, but will, it is hoped, be excused.

The following experiments were made with especial reference to the mechanism of the second sound.

1. Pressure with the finger and thumb was exerted on the arteries close to the sigmoid valves, so as to flatten the tubes a little, and the second sound, previously clear, and in every respect normal, was immediately suppressed, and a bellows murmur was heard instead: this murmur ceased, and the normal sound returned instantly on the removal of the fingers. Eperiments 7 and 10.

2. A degree of pressure sufficient, it was conceived, to change, but very slightly, the shapes of the vessels, gave to the finger sensations of currents moving in opposite directions; the one current more striking, and coinciding with the systole; the other less forcible and synchronous with the diastole, and ending suddenly by a sensation of flapping or jerking. Experiment 14.

3. The fingers being applied gently to the region of the sigmoid valves, and the ear-tube applied to the heart, the flapping sound was heard, and a sensation of a gentle tap was felt by the finger, in coincidence with the diastole and second sound. Experiments 10 and 14.

4. One valve of each set of sigmoids was hooked up in each artery successively, and the jerking motion invariably ceased, with one *apparent* exception only, and continued suppressed in the

artery in which a valve had been so hooked up. If a valve in one artery only was so engaged, the second sound was weakened; but if a valve of each set of sigmoids was fixed, then the second sound wholly disappeared. In some instances there was a murmur of the sucking or blowing kind following the systole during the suspension of the valve; in other instances there was absence of sound simply. Experiments 4, 6, 12, 13.

5. The arteries were cut across close to the sigmoid valves, the veins being left entire, and the heart beating with considerable force; the ear-tube was then applied, but gave only one sound, and that one coincident with the systole. Experiment 14.

6. In the separated heart the first sound was repeatedly observed, but the second sound never.

Summary of Conclusions.—1. The first sound of the heart, as heard in the chest, is generally complex in its nature, consisting of one constant or essential sound, and one perceptible only under certain circumstances; this constant element of the first sound may be considered as intrinsic, appearing to depend on the sudden transition of the ventricles from a state of flaccidity in diastole to one of extreme tension in systole; while the extrinsic or subsidiary sound, which generally accompanies and increases the intrinsic sound, arises from the impulse of the heart against the parietes, chiefly of the thorax.

2. The collisions of the particles of the blood amongst each other, or against the interior parietes, valves, &c. of the heart, do not appear to have any share in the normal first sound of the heart; neither do the motions of the auriculo-ventricular valves; and the attrition of the opposite interior surfaces of the heart's cavities seems purely hypothetical.

3. The principal, and apparently only, cause of the second normal sound of the heart, is the sudden closure of the sigmoid valves by the columns of blood that recoil back on them during the diastole, impelled by the elastic contraction of the arteries.

4. The columnæ carneæ appear to act simultaneously with the parietes of the ventricles, and in such a manner as to make it apparently impossible that the auriculo-ventricular valves should close with a flap, in the same manner as the sigmoid valves.

Note. An opinion which is further confirmed by the anatomy of the heart of the domestic cock, in which M. Bouillard appears to have heard both sounds with the naked ear. In that animal there is no tricuspid valve resembling that of man, but the valvular office is discharged by laminar extensions of the substance of the parietes of the ventricle, which meet in the middle, so as, during the systole, to cover the auriculo-ventricular orifice.

To conclude,—The Committee feel strongly that the subject

of the heart's motions and sounds requires further investigation, more especially in their pathological relations, and a wider range and greater variety of experiments than have hitherto been performed.

(Signed) C. J. B. Williams, M.D. F.R.S.
R. B. Todd, M.D., Oxon, Professor of Physiology, King's College, London.
John Clendinning, M.D., Edin. and Oxon, Fellow of the R. C. of Physicians, Hon. Sec. Royal Med. Chir. Society, Physician to the Marylebone Infirmary, and Reporter.

Second Report of the Dublin Sub-Committee on the Motions and Sounds of the Heart. (See vol. iv. p. 243.)

§ I.—The Dublin Committee for investigating the motions and sounds of the heart, re-appointed by the British Association at their last Meeting, have considered the following questions submitted to them by the General Committee of the Association.

1. Whether the muscular fibres of the columnæ carneæ contract at the same precise moment as the mass of muscular fibres of the ventricle?

2. What is the precise mode in which the tricuspid and mitral valves prevent the reflux of blood? Are they floated up and stretched across the auriculo-ventricular orifices, or drawn together to a point within the cavity of the ventricle by the action of the columnæ carneæ?

In order to solve the former of these questions the Committee have several times repeated the experiment of opening the heart, either while within the body of the newly killed animal, or suddenly removed from it and placed in tepid water, in the expectation that the movements of the fleshy columns and of the general mass of the ventricles might be compared by inspection and their relations as to time thus ascertained. But in every instance it was found that the injury thus inflicted upon the heart caused its death so rapidly that no satisfactory conclusion could be drawn from these experiments.

Independently of any direct experiment on this subject there are many considerations which, in the opinion of the Committee, serve to prove that the question now under view should be answered in the affirmative.

The fleshy columns which are attached to the valves, and which have, for the sake of distinction, been called by some "papillary muscles," differ from the other fleshy columns in the circumstance of being connected to the substance of the ventricle only at one of their extremities, while the other is conjoined to the "chordæ tendineæ," but their fibres are, equally as those of the ordinary fleshy columns, continuous with the fibres of the general mass of the ventricles. That the ordinary fleshy columns contract simultaneously with the systole of the ventricles there can be no doubt, as the shortening of those columns is necessary to the completeness of the systole; and as the papillary muscles resemble the ordinary fleshy columns in the continuity of their fibres with those of the ventricles, it is reasonable to

suppose that the contractions of the former as of the latter class of fleshy columns are synchronous with those of the general mass. In the second place it is to be considered that if the papillary muscles were not in a state of contraction during the whole of the ventricular systole, the valves to which they are attached would be driven up by the impulse of the blood into the auriculo-ventricular openings, and thus become unfitted for their office, as is seen in the dead heart, in which a stream of water injected into either ventricle by its artery, drives the valves towards the auricle until the water escapes between their edges. It is to be observed also that in many quadrupeds, and to a certain extent in the human subject, some of the tendinous cords attached to a valve are connected to papillary muscles, while the remainder are inserted directly into the surface of the ventricle: but it cannot be supposed that the former set of tendons are at rest while the latter are acted upon by the general ventricular contraction.

To the solution of the second question a consideration of the manner in which the mitral and tricuspid valves are connected with their respective papillary muscles, and of the relation of these to the rest of the substance of the heart is necessary. Each of these valves may be regarded as a portion of a hollow membranous cylinder, attached by one edge around the auriculo-ventricular opening, the other edge projecting into the ventricle and connected to certain of the tendinous cords. The greater number of these, however, are joined to the valve, not at its edge, but at various points of its ventricular surface. The ventricular, or moveable edges of those valves are extremely irregular in their outline, being deeply notched in some parts and projecting in others; but as to their mode of operation each valve may be considered as consisting of two flaps, a larger and a smaller one, by the application of which to each other during the ventricular systole the blood is prevented from regurgitating into the auricles. The large flap of the mitral valve is placed between the orifice of the aorta and the left auriculo-ventricular opening, nearly in a horizontal plane, the heart being supposed to be in its natural position, and the person in the upright posture, and may be described in reference to the smaller flap as superior, somewhat anterior, and a little to the right side. The smaller flap is placed opposite to the larger, and is, with regard to it inferior, somewhat posterior and a little to the left. When these flaps are in opposition during the systole of the ventricle, the line of their contact is of a somewhat semilunar form, and in the transverse direction.

The larger flap of the tricuspid valve is attached to that part of

the margin of the auriculo-ventricular opening which corresponds to the portion of the ventricle not formed by the septum, and may be described, with reference to the smaller flap, as being placed externally to it, and to its right side : the smaller flap is connected to that portion of the margin of the opening which corresponds to the septum, and is, with regard to the larger flap, internal and to the left side. When these flaps are in contact with each other during the ventricular systole, the line of their junction is vertical, being very nearly at right angles to the analogous line as described in the mitral valve.

The papillary muscles of the mitral valve vary in number in different subjects, but there are always two larger than the others, arising from the posterior wall of the ventricle, about midway between the apex and the base, one of which is situated close to the septum, and the other at the external edge or part of the posterior wall. They are somewhat flat-shaped, and are nearly parallel to each other and to the axis of the ventricle. Each of these papillary muscles terminates in two or three papillæ of nearly equal length, and whose summits are about one-fourth of an inch asunder. From these summits proceed, in a radiating form, a great number of tendinous cords, which are distributed to the flaps of the valve in the following manner: those cords which arise from the superior papilla on each side are connected to the superior or larger flap; those from the papilla on each side, situated between the superior and inferior, are distributed partly to the larger flap, and partly to that portion of the valve where the larger and smaller flaps are conjoined; and the cords arising from the lowest papilla on each side are connected chiefly to the smaller or inferior flap. Besides the two papillary muscles just described there are others smaller, which arise from the posterior wall of the ventricle, nearer its base, at a situation corresponding to the attachment of the smaller flap, to which flap the tendons proceeding from these muscles are distributed.

In the right ventricle the papillary muscles connected with the larger flap are three or four in number, and arise near the apex of the ventricle by footstalks proceeding generally both from the septum and from the external wall of the ventricle. They are somewhat flat in shape, nearly parallel in their direction to the axis of the ventricle, and placed at intervals of half or three quarters of an inch from each other, measured along the external wall of the ventricle, which is of a curved form, and seems to be wrapped round the septum. From the papillæ by which these muscles are terminated proceed a number of tendinous cords, which are distributed in a radiating manner to the surface and margin of the larger flap. The superior part of this mar-

gin, just where the larger and smaller flaps are about to conjoin, receives one or two tendinous cords, which proceed directly from the septum, without the intervention of any papillary muscle. The smaller flap receives one or two of its tendons from the lowest in position of those papillary muscles which have been described as supplying the larger flap; but all the others which it receives, to the number of 12 or 14, proceed to it directly from the surface of the septum, near the base, no papillary muscle intervening.

From an inspection of the arrangement now described it is manifest that the papillary muscles, when they contract, draw the tendinous cords more or less towards the axis of the respective auriculo-ventricular openings; and if it be supposed that by any cause the flaps have been laid against the sides of the ventricles, the contraction of the papillary muscles will remove from such situation, or adduct towards the auriculo-ventricular axis, those portions of the valves to which they are connected.

It is also clear that the contraction of the papillary muscles cannot, in any instance, close the valves, or bring their flaps into contact with each other. For when the contraction of the papillary muscles is at its greatest, as at the end of the ventricular systole, if it be assumed that the cords and flaps of the valves have been rendered tense by their action, leaving altogether out of view, for the present, the influence of the blood upon the valves; and further, if it be supposed that the numerous summits of papillæ, whence the cords proceed, have been gathered in each ventricle into a single point; in such a state of things each valve and its cords will have assumed a form resembling an irregular funnel, of which the base is at the auriculo-ventricular opening, and the apex at the point of conjunction of the summits of the papillæ: and it is evident that the opposite points of the moveable edge of each valve will be separated from each other by spaces equal to corresponding diameters of the funnel. The assumption that the summits of the papillæ are congregated into a single point at the latter part of the systole is manifestly incorrect, as the swelling of the papillary muscles, during contraction, will tend rather to separate from each other those summits which arise from the same papillary muscle; but in order that the edges of the valves should be brought into contact by the action of the papillary muscles *alone*, such an arrangement of those muscles would be necessary as should cause the tendons of the opposing flaps to cross each other during the systole, an effect totally incompatible with the present construction of the organ under consideration.

It is also an erroneous assumption that the valves are rendered tense by the action of the papillary muscles, unaided by the influence of the blood upon the surfaces of the valves: for, were it true, by the time when the contraction of these muscles is at its greatest, and for some time previous, the valves would be held by them in an open state, as has just been proved; and thus during a portion of the systole, towards its end, the closing of the passages into the auricles would be rendered incomplete. It is accordingly inconsistent with the functions of the heart that the papillary muscles, in their state of greatest contraction, should render the valves tense: it follows that they cannot render them tense at any previous stage of contraction.

The valves are closed by the impulse communicated to them through the blood at the commencement of the systole; and are prevented from separating during its continuance by the same cause. The papillary muscles have for their office to regulate the position of the valves, and to prevent them from being driven so far towards the auricles as to render incomplete the closing of their orifices. It does not appear that the action of the papillary muscles is at all necessary for the removal of the flaps from the sides of the ventricles, in order that the blood may be admitted between them at the commencement of the systole: for in the dead heart, if water be injected into either ventricle, through its corresponding artery, or through a hole made in its apex, it never fails to float the valves towards the auricles, and to bring their respective flaps into close contact. If force be used in this experiment the valves are driven into the auriculo-ventricular openings, and the water escapes between their edges. In this experiment it is seen also that the tricuspid valve performs its office as completely as the mitral, opposing a perfect obstacle to the flow of blood until force is employed.

It is probable that in the living heart the valves are not applied close to the sides of the ventricles, when these are in their diastole, and full of blood; but that an interval exists between them occupied by this fluid. The central position of the papillary muscles of the larger flaps, and the shortness of their tendons are favourable to this supposition; and, in the right ventricle, the mode in which the smaller flap is connected to the septum, by tendons inserted directly, and without papillary muscles, requires for the closing of this portion of the valve, that the blood should have insinuated itself between it and the adjacent surface, previously to the commencement of the systole, inasmuch as the mere muscular contraction of the ventricle is

incapable of drawing this flap from the adjoining surface; and were the systole to commence while this portion of the valve was applied to the side of the ventricle, the impulse of the blood would be expended upon its auricular, instead of its ventricular surface. In many quadrupeds, for instance, in the calf, the papillary muscles are almost altogether wanting in both sides of the heart: the tendons of the valves are inserted directly into the surfaces of the ventricles, and are so short that it is manifestly impossible that the flaps can be laid against the sides of those cavities when they are distended with blood.

In the dead heart, placed in water, the valves do not hang down in the fluid, but assume a cup-like form, and their free edges are puckered together; thus manifesting a disposition to acquire, without the aid of the muscles, that figure and position which are most favourable for receiving the impulse of the blood.

When the ventricular systole begins, the valves are closed by the muscular power of the ventricles transmitted to them through the blood, and the papillary muscles, commencing their contraction at the same moment, are enabled to resist the impetus by which, but for their aid, the valves would be driven unduly towards the auricles. The valvular flaps are now in contact with each other by a portion of their auricular surfaces adjacent to their free edges, and their form is curvilinear like that of a sail distended by the wind; a form of surface which, it may be observed, enables the papillary muscles to resist the impetus of the blood by a much less expenditure of their power than had the valves been rendered tense in the first instance, and drawn to a point by the action of these muscles alone. As the systole proceeds, all the parts of the ventricles approach, more or less, to the base; and thus the distance which at the beginning of the systole intervened between the auriculo-ventricular openings and the more remote extremities of the papillary muscles, is gradually abridged. The gradual contraction of these muscles serves to compensate for the diminution of this distance, and thus the valves are retained in an unaltered position from the beginning till the end of the systole.

This view of the purpose which the contractile power of the papillary muscles is intended to fulfil, is strengthened by observing that those papillary muscles are the longest which have their origin from the substance of the ventricles most remote from the base of the heart, and that they are found to be shorter in proportion as their origins are nearer to that part; and the tendinous cords of the smaller flap of the tricuspid valve, which

arise from the septum very near the base, proceed from its surface to the margin of the valve without the intervention of any papillary muscle.

This method of arrangement evidently depends upon the general law of muscular contraction, according to which the shortening of a fibre bears a definite ratio to its length in the uncontracted state. The parts of the ventricle most remote from the base receive the longest fibres, and accordingly make the greatest degree of approach to it during their period of contraction.

§ II.—The Committee have repeated many of their former experiments with regard both to the motions and sounds of the heart, and have derived from them a confirmation of the views detailed in their last Report. In order to elucidate the cause of the sounds of the heart the following new experiments have been performed.

Experiment 1.—In a calf, prepared in the manner described in the former Report, the thorax was opened, and the apex of the heart cut off, so that the blood, during the contraction of the ventricles, flowed into the chest, instead of passing into the large arteries. An ear-tube being applied to the body of the ventricles, one sound only was heard, resembling the first sound of the heart, and coinciding with the ventricular systole. When the blood had ceased to flow, a finger was inserted into the left ventricle, by which it was firmly grasped at each contraction, and the ear-tube being again applied to the surface, a sound, which may be described as a *dull thump*, was heard simultaneously with the grasp of the finger by the ventricle.

Experiment 2.—A stop-cock, communicating at one end with a large bladder full of water, was inserted into the right auricle of a human heart, and secured by a ligature. A glass tube, $2\frac{1}{2}$ feet long, and $\frac{7}{8}$ inch in bore, was tied into the pulmonary artery, one inch above the semilunar valves. The bladder pressed upon so as to fill the right ventricle, which was then compressed at intervals by the hand, and thus the fluid was sent into the tube by jerks, in imitation of the natural action of the heart. An ear-tube being applied to the surface of the heart, two sounds were heard, one prolonged, the other abrupt, very closely resembling the natural sounds of the beating heart. The former sound was heard during the contraction of the hand, the latter immediately upon its relaxation. During the first sound the fluid ascended in the tube, and descended a little when the second sound was heard. The tube was now taken out of the artery; the semilunar valves were completely removed, and the tube was reinserted and fixed as before. The alternate compression of the

ventricle by the hand, and relaxation being renewed, two sounds were heard, both prolonged, the second having lost the abruptness by which it had been previously characterized.

Experiment 3.—The experiment now to be described was first made by M. Rouanet, and is detailed by M. Bouilleaud, in his work on the diseases of the heart. It consists in attaching by one end, a glass tube a few inches in length, and about an inch wide, to a bladder holding water, and by the other to the aorta, close beneath the semilunar valves, but so as not to interfere with their movements; the muscular substance of the heart having been previously removed. Another glass tube, some feet long, and of equal diameter with the former, is tied into the aorta at a distance of two or three inches above the semilunar valves. The bladder is compressed by the hand so as to raise the water in the tube to a considerable height; and the hand being suddenly relaxed, the column of water in the longer tube, deprived of support, descends until it is arrested by the closing of the semilunar valves. At this instant, if the ear have been applied to the lower part of the longer tube, an abrupt sound is heard, resembling the second sound of the heart. If the semilunar valves be now removed, and the experiment with this alteration, be repeated, the sound, which is heard to accompany the relaxation of the heart, is no longer abrupt, but prolonged.

The conclusions which the Committee have drawn from these experiments, as to the causes of the ordinary sounds of the heart, are similar to those detailed in their former Report, to which they beg leave to refer.

It appears to the Committee that many writers upon the sounds of the heart have not sufficiently distinguished the characters of those sounds, the prolongation of the first, and the abruptness of the second; and the term "tic-tac" which has been employed to express their rythm, is likely to mislead inaccurate observers by representing the sounds as of equal length.

The first sound, of a homogeneous character, beginning and ending with the ventricular systole, which is a prolonged action, coincides with it in duration; and the observation of this fact has enabled the Committee to exclude from the causes of the first sound, all those which are of a momentary nature, as the closing of valves, and those possessing the character of impulse.

In concluding their second Report, the Committee wish to state their opinion that the motions and sounds of the heart have been now, by themselves and others, investigated nearly as far

as can be done by mere experiment; but that much light can be thrown upon the subject, and the truth of theories tested, by the observation of disease. To this part of the subject, the Dublin Committee propose to apply themselves during the ensuing year, if it be the wish of the Association that their inquiries should be continued.

(Signed) JAMES MACARTNEY, M.D., F.R.S.
ROBERT ADAMS, A.M., T.C.D.
EVORY KENNEDY, M.D.
GEORGE GREENE, A.B., M.D.
JOHN HART, M.D.
WM. BRUCE JOY, A.M., M.B.
JOHN NOLAN, M.D.
ROBERT LAW, M.D.
H. CARLILE, A.B., T.C.D.

August 19*th*, 1836.

Report of the Dublin Committee on the Pathology of the Brain and Nervous System.

THE Committee appointed in Dublin to investigate the "Pathology of the Brain and Nervous System," feel compelled, on the present occasion, to confine themselves to an analysis of the cases of nervous affections which have come under their observation, during the short period which has elapsed since they have considered themselves to be regularly appointed.

They are of opinion that in order to arrive at accurate pathological conclusions on a subject so extensive and complicated, and on which the most eminent authorities are found to disagree, a very great number of cases should be first submitted to their examination—then, the symptoms of each case carefully registered—and, subsequently accurate post mortem examinations made, in the presence of the Committee, to ascertain the structural lesion or lesions with which the symptoms co-existed.

As far as their investigations have as yet extended, they see that the subject, if considered in all its details, will require a considerable length of time before they can accumulate such a number of cases and matured observations as would justify them in drawing general conclusions.

They have collected some valuable facts relating to injuries and diseases of the nerves, which seem to throw light upon the disputed points of the physiology and pathology of this portion of the nervous system. They are of opinion, however, that more extended observations on this branch of the subject are required to be made. They would also submit the necessity of repeating those experiments, upon which so many rely as a foundation for their doctrines.

They have been for some time engaged in registering the history and symptoms of cases of nervous affections in the Wards of the House of Industry, Dublin, and the different Hospitals belonging thereto.

They find that this Institution presents ample materials for a future report, should they be re-appointed, the number of cases of mental and nervous diseases which it contains being, independently of about 150 cases of paralysis, as follows, viz.

	Males.	Females.	
Chronic Insane	74	179	
Epileptic Insane	21	33	
Congenital Idiots	69	62	
Epileptic Idiots	14	20	
	178	294	Total 472

The number of cases which the Committee have been enabled to examine with sufficient accuracy, amounts to forty-one. Of these they have made an analysis which is attached to their Report. They also affix an index referring to seventeen cases of affections of individual nerves, but regret that they have not had sufficient time to make either as full and accurate as they could wish.

(Signed) James O'Beirne, M.D.
George Greene, M.D.
John Macdonnell, M.D.
Robert Adams, A.M., T.C.D.

Dublin, August 17*th*, 1836.

Account of the recent Discussions of Observations of the Tides which have been obtained by means of the grant of Money which was placed at the disposal of the Author for that purpose at the last Meeting of the Association. By J. W. Lubbock, *Esq.*

I wish to lay before the Section the points to which I have chiefly directed my attention on the subject of the tides since the last meeting of the Association, aided by the grant of money which was placed at my disposal, and for which I beg to offer my warmest acknowledgements.

In the first place I requested Mr. Dessiou to separate into different categories his discussion of the Liverpool tides for the calendar months, so as to ascertain the difference between the morning and evening tides on the same day, or the diurnal inequality. This inequality is extremely sensible at Liverpool in the height, as may be seen in the diagram and tables which I prepared, with Mr. Dessiou's assistance, and which are published in the *Phil. Trans.*

Mr. Dessiou also, at my request, classified the errors of prediction for a year at Liverpool, and also of a year at London, in order to deduce the influence upon the tide of variations in the atmospheric pressure. I have thus succeeded in confirming the result first obtained by M. Daussy from the observations at Brest, namely, that the height of high water is less when the barometer is high, and *vice versâ*. In the Report which I had the honour formerly to present to the Association, I expressed the opinion that the tides in the river Thames did not warrant this inference; this opinion was founded upon the rough examination of a year's observations, and it is now completely disproved.

I have also been enabled to procure the assistance of Mr. Jones and Mr. Russell, two excellent computers. These gentlemen, under my guidance, have discussed the observations of 19 years at the London Docks. These observations were formerly discussed by Mr. Dessiou with reference to the moon's transit immediately preceding. But upon examining the results thus obtained I saw that for the interval no satisfactory comparison with theory could be obtained for the moon's parallax and declination corrections in this manner, and that it was indispensible to refer the phænomena to the tide-producing forces at a period more remote. The law of the *intervals*, when the discussion is instituted with reference to the transit immediately preceding the time of high water, whether at London, Liverpool, or Brest, de-

pends partly upon the phænomena as deducible from Bernoulli's equilibrium theory, and partly upon the law of the intervals between the moon's successive transits. I therefore directed Mr. Jones and Mr. Russell to discuss the observations with reference to the fifth transit preceding, or that two days before the high water under consideration.

The results which we obtained, and the comparisons with theory which I instituted, are printed in the *Phil. Trans.* The observations of 19 years amount to 13,370; but notwithstanding their multiplicity, when they come to be separated into numerous categories, as for the purpose of ascertaining the diurnal inequality, the irregularities which the results present show clearly that even a greater number is required in order to arrive at averages which can be sufficiently depended upon. Still the general conclusion to which my discussions lead is that the equilibrium theory of Bernoulli satisfies the phænomena nearly if not quite within the limits of the errors of the observations, and that it leaves very little, if anything, to be accounted for otherwise.

This question is extremely interesting, and seems to me to deserve the fullest investigation which the materials within our reach can justify. If the discussion were extended by taking in all the observations which have been made at the London Docks (which would give us about 16 years more, or nearly double the number), I have no doubt that the results would be much more free from irregularity. It would also be worth while to bring up the interval and the height to what they ought to have been in Tables* I. and X. if the moon's parallax had been exactly 57′, and in Table VI. to what they ought to have been if the moon's declination had been exactly 15°. I have hitherto neglected the minute quantities, which would thus have given a second approximation on account of the great additional labour which they would have occasioned, but I have no doubt that something would be gained by supplying this correction.

Besides all the work which I have detailed, the grant of the Association has enabled me to employ Mr. Jones to effect a discussion of the Liverpool observations for 19 years, also with reference to a back transit in order to obtain the calendar month and diurnal inequalities. It would be desirable to complete this discussion, in order to obtain in the same manner the moon's parallax corrections. It would also be desirable to extend the

* *Phil. Trans.* 1836. The correction for the difference of the moon's declination from 15° is, I apprehend, insensible, and that for the difference of the moon's parallax will seldom, if ever, exceed one minute for the interval, and one tenth of a foot in the height.

discussion of the Liverpool tides by employing more of the Hutchinsonian observations.

If the Brest observations were published it might be better to proceed at once with their discussion, abandoning, if necessary, for the present our Liverpool and London investigations. The observations there have no doubt been carefully made, and the situation of the port may appear to some to present advantages. These advantages I am convinced have been much overrated, and I attribute the extreme apathy which has been evinced on the subject of the tides in this country until lately to the erroneous idea that little could be reaped from observations at places so far removed from the open ocean as London. However I feel much regret at being deprived of the opportunity of recurring to the Brest observations, particularly as I am informed they have long since been printed.

A Paper was communicated entitled Observations for determining the refractive Indices for the Standard Rays of the Solar Spectrum in various media. By the Rev. BADEN POWELL, *M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.*

THIS paper contained the details of the observations in a tabular form, printed copies of which were distributed. The author prefaced them by a brief statement of the circumstances which had led to them, and of their nature. The determination of the refractive indices for definite rays of the solar spectrum marked by the dark lines, from the direct observations of their deviations produced by prisms of different substances, first proposed and executed by Fraunhofer, for ten media solid and liquid, was carried on by M. Rudberg for ten more cases. The necessity for an extended series of such determinations was pointed out and strongly insisted on by Sir J. Herschel, as well as by Sir D. Brewster; and was further urged by a special recommendation from the British Association. (*Third Report*, p. 319.) Not being able to learn that anything has been done towards supplying the deficiency in other quarters, the author took up the inquiry; and the tabular statements contain the results of observations, in which he has attempted to ascertain the refractive indices belonging to each of the standard primary rays for various media: comprising in the present instance the only highly dispersive substances he has been as yet able to procure in a condition capable of prismatic observation; together with some other liquids of different natures: this being a first contribution only towards a series of such determinations, which he hopes to continue.

Provisional Report on the Communication between the Arteries and Absorbents on the part of the London Committee. By Dr. HODGKIN.

Dr. Hodgkin read to the Medical Section a provisional Report on behalf of the London Committee appointed to investigate the communications between the arteries and absorbents. As the Committee is continued to pursue the inquiry, the author has not transmitted the Report for publication in the present volume. The following are the outlines of the Report.

The Committee had added to its number Mr. Francis Sibson, jun., an expert and practised anatomist then engaged at Guy's Hospital, where it was found most convenient for the inquiry to be conducted. Numerous examinations were made of the lacteals in man and other animals, in which these vessels were either filled with chyle, or artificially injected with mercury, but no positive instance of a lacteal communicating with the veins was discovered. Two instances were mentioned in which an efferent vessel from a mesenteric gland entered a large vein, but there was reason to suspect that the vessels, which appeared to belong to the lymphatic system, were really veins. The communication between the absorbents and veins in the substance of the mesenteric glands was confirmed in numerous instances, and under circumstances which induced the reporter to believe that no rupture or extravasation had taken place. Although the views of Professor Lippi had not been confirmed by the examiners, the reporter did not conclude that they were to be wholly rejected, and the thoracic duct and right trunk regarded as the sole communications between the absorbent and venous systems, since numerous anatomists had seen and described other instances of absorbents entering veins. He had himself seen the absorbents from a lung entering the vena azygos, and his friend Mr. Bracy Clark had found the receptaculum chyli emptying itself into a lumbar vein. He was inclined to believe that such communications occurred as anomalies and variations analogous to other varieties in the distribution of vessels. This view derived some support from the fact that such communications occurred chiefly in or near the neck, and in the pelvis, where they resembled the normal distribution observed in birds and reptiles. There was then an analogy between these irregularities of the absorbent system, and the most frequent varieties in the arterial, which also, for the most part, resemble the normal distribution in some of the inferior animals. It did not appear that Lippi was able to demonstrate the com-

munications for which he contended, in every subject, and the care which he had taken to describe and delineate them when met with seemed to indicate that they were comparatively rare, even amongst his numerous examinations. Amongst the facts connected with the inferior animals, the author remarked that in the kangaroo he had found that the thoracic duct was double, affording another instance of similarity between the circulation in that animal and in birds, and noticed the very considerable dilatation of the receptaculum chyli which he had met with in a fœtal pig. The Report also contained some notice of the labours of Müller, Arnold, Fohmann, Panizza, and Drs. Thomson and Sharpey on this subject, as well as the recently published thesis of Professor Brechet. In relation to the origins of the lymphatics, he noticed the fact observed by Mr. T. King, that the lymphatics of the thyroid gland were found filled with the very peculiar secretion proper to the cells of that organ, and that he had himself seen the lymph in the thoracic duct of the pig flowing alternately colourless and highly sanguinolent, which, as no violence had been done to the abdomen, appeared to indicate some natural but unexplained communication between the sanguiferous and lymphatic systems. The Report concluded with some observations respecting the formation of vessels, in which the author endeavoured to account for the exact correspondence which often exists between arteries and veins, and also for the production of valves in the latter vessels and in absorbents.

Report of Experiments on Subterranean Temperature, under the direction of a Committee; consisting of Professor Forbes, Mr. W. S. Harris, *Professor* Powell, Lieut.-Col. Sykes, and *Professor* Phillips (Reporter).

Having noticed the principal causes of error in experiments on the temperature of the air, water, rocks, and metallic veins below the surface, the author described the methods and instruments of research recommended by a Committee of the Association to eliminate the known and neutralize the unknown sources of fallacy. The instruments constructed for this purpose were properly placed in many situations, under the direction of competent persons, and satisfactory results had already been obtained, which in every instance agreed with the general results of foreign inquiries in proving a continual augmentation of heat below the surface of invariable temperature. At the Lead Hills Professor Forbes had placed thermometers under the care of Mr. Irvine; Mr. Buddle had established registers at Newcastle; Mr. Anderson, at Monk Wearmouth; Mr. Hodgkinson, near Manchester; and within a few days Professor Phillips had been enabled through the kindness of a friend to place a thermometer in a deep coal mine at Bedminster, near Bristol. Similar instruments have since been extensively distributed, and the following general instructions and form of register have been prepared for the assistance of observers.

Instructions for conducting experiments on the Temperature of the Earth, at various depths, upon a plan and with instruments recommended by a Committee of the British Association for the Advancement of Science.

The general interest and importance of inquiries into the interior temperature of the earth render it proper to explain, to those who may be engaged in conducting the experiments, that for the purpose of obtaining results really valuable, and capable of being combined in philosophical investigations, *it is essential* that the same object of research should be proposed,—the same plan of experiment followed,—and similar instruments employed; —*it is convenient* that the results obtained should be recorded in tables of one form, and transmitted to one person, named by the Association, for the examination of the Committee.

(*a.*) *The object* proposed to be accomplished, by the experiments contemplated, is the acquisition of satisfactory data, for the establishment of undoubted conclusions concerning the real

temperature of the interior of the earth, from the surface to the greatest depths yet reached by human enterprise.

(*b.*) *The plan of experiment* proposed for general adoption, and specially required to be followed by those who undertake to use the instruments furnished by the Association, is intended to reduce the effect of known and equalize those of unknown sources of fallacy.

For this end certain precautions must be observed, suited to experiments in air, water, and rock respectively; for none of these are wholly free from the influence of sources of serious error.

The temperature of the air in the gallery of a mine varies according to the place of the observation as compared with the entrance and exit of the current; according to the rate of this current as it passes through a confined, open, or complicated passage; according to the place of the thermometer in the section of the air passage; according to lights, respiration, and other local conditions.

On all these accounts the experiments in air are the least accurate indications of subterranean temperature: however carefully made there is in the result always too much of the effect of local influences which cannot be estimated. (They are however extremely valuable in combination with those hereafter noticed.)

The water of a mine offers a less exceptionable subject of experiment. If it be a small continuous subterranean spring, discovered at a known depth, without any sign of efflux under violent pressure, its temperature carefully taken will be found to be nearly constant. The composition and specific gravity of the water may be of importance in the combination of the results. It should therefore be correctly stated. But water merely lying in the galleries of a mine, or collected from the sides of the shafts, is never to be referred to as a standard of subterranean temperature.

It is however in the solid rock that the best observations, and those most suited to the purpose of philosophical reasoning, are to be obtained. The principal sources of fallacy in this class of experiments arise from the unequal and varying influences of the air-currents, moisture, &c., on the surface of the rock; local chemical actions and electric currents may also be noticed as affecting the precision of the result, and if known should be recorded. The only experimental caution, however, available in this case, is to sink the thermometer to a sufficient depth from the surface, in a hole very little larger than itself, and to record the observations after moderate intervals of time.

(*c*) *The instruments* furnished have been compared with one known standard, and all that is required of the observer is to re-

cord exactly their indications under the conditions mentioned in the following table; of which separate copies have been furnished, so as to have all the entries as uniform as possible, and duplicates to enable the observers to retain a copy. *The original is to be folded and forwarded to "Professor Phillips, Assistant General Secretary to the British Association, York."*

Weekly Register of Observations on Subterranean Temperature at in Lat. , Long.

Elevation of the surface above the sea in feet*.
Mean annual temperature of the air at surface.
Mean temperature of permanent springs issuing from rock.

Year, Month, and Day.	Thermometer (No.) exposed for half an hour in the following situations, and in the following order of succession.				Thermometer (No.).	Thermometer (No.).
	In air: in the shade 4 feet above the ground.	In air: in the mine or colliery near the base of the cold-air shaft. Depth ( ).	In air: in the mine or colliery near the base of the hot-air shaft. Depth ( ).	Immersed in a subterranean spring: if constant†. Depth ( ).	In a hole of rock‡ 3 feet deep. Depth from surface. ( ).	In another hole of rock‡ 3 feet deep. Depth from surface. ( ).
January.						
Averages.						

* The *half-tide level* is supposed to be the best standard of sea level: the elevation of the surface may be found by levelling, trigonometry, the barometer, or by comparison with navigations or railways. The method of determination should be stated.

† The quality of water should be stated, as salt, chalybeate, ordinary.

‡ State whether the rock be argillaceous, calcareous, or arenaceous. If experiments be made in rock dykes or mineral veins, another thermometer should be placed at the same depth in the neighbouring rock.

Inquiry into the Validity of a Method recently proposed by George B. Jerrard, *Esq., for Transforming and Resolving Equations of Elevated Degrees: undertaken at the Request of the Association by Professor* Sir W. R. Hamilton.

[1.] It is well known that the result of the elimination of x, between the general equation of the m^{th} degree,

$$\left.\begin{array}{l} X = x^m + A\,x^{m-1} + B\,x^{m-2} + C\,x^{m-3} + D\,x^{m-4} \\ \qquad + E\,x^{m-5} + \&c. = 0 \end{array}\right\} \quad (1.)$$

and an equation of the form

$$y = f(x), \quad . \ . \ . \ . \ . \ . \ . \quad (2.)$$

(in which $f(x)$ denotes any rational function of x, or, more generally, any function which admits of only one value for any one value of x,) is a new or transformed equation of the m^{th} degree, which may be thus denoted,

$$\{y - f(x_1)\}\ \{y - f(x_2)\} \dots \{y - f(x_m)\} = 0, \quad . \ . \quad (3.)$$

$x_1, x_2, \dots x_m$ denoting the m roots of the proposed equation; or, more concisely, thus,

$$\left.\begin{array}{l} Y = y^m + A'\,y^{m-1} + B'\,y^{m-2} + C'\,y^{m-3} + D'\,y^{m-4} \\ \qquad + E'\,y^{m-5} + \&c. = 0, \end{array}\right\} \quad (4.)$$

the coefficients A', B', C', &c., being connected with the values $f(x_1), f(x_2)$, &c., by the relations,

$$\left.\begin{array}{l} -A' = f(x_1) + f(x_2) + \&c. + f(x_m), \\ +B' = f(x_1)f(x_2) + f(x_1)f(x_3) + f(x_2)f(x_3) + \&c. \\ \qquad\qquad + f(x_{m-1})f(x_m), \\ -C' = f(x_1)f(x_2)f(x_3) + \&c. \end{array}\right\} \quad (5.)$$

And it has been found possible, in several known instances, to assign such a form to the function $f(x)$ or y, that the new or transformed equation, $Y = 0$, shall be less complex or easier to resolve, than the proposed or original equation $X = 0$. For example, it has long been known that by assuming

$$y = f(x) = \frac{A}{m} + x, \quad . \ . \ . \ . \ . \ . \ . \ . \quad (6.)$$

one term may be taken away from the general equation (1); that general equation being changed into another of the form

$$Y = y^m + B' y^{m-2} + C' y^{m-3} + \&c. = 0, \quad . \quad . \quad . \quad (7.)$$

in which there occurs no term proportional to y^{m-1}, the condition

$$A' = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8.)$$

being satisfied; and Tschirnhausen discovered that by assuming

$$y = f(x) = P + Q\,x + x^2, \quad . \quad . \quad . \quad . \quad . \quad . \quad (9.)$$

and by determining P and Q so as to satisfy two equations which can be assigned, and which are respectively of the first and second degrees, it is possible to fulfil the condition

$$B' = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10.)$$

along with the condition

$$A' = 0, \quad . \quad . \quad (8.)$$

and therefore to *take away two terms* at once from the general equation of the m^{th} degree; or, in other words, to change that equation (1) to the form

$$Y = y^m + C' y^{m-3} + D' y^{m-4} + \&c. = 0, \quad . \quad . \quad . \quad (11.)$$

in which there occurs no term proportional either to y^{m-1} or to y^{m-2}. But if we attempted to take away *three terms* at once, from the general equation (1), or to reduce it to the form

$$Y = y^m + D' y^{m-4} + E' y^{m-5} + \&c. = 0, \quad . \quad . \quad (12.)$$

(in which there occurs no term proportional to y^{m-1}, y^{m-2}, or y^{m-3},) by assuming, according to the same analogy,

$$y = P + Q\,x + R\,x^2 + x^3, \quad . \quad . \quad . \quad . \quad . \quad (13.)$$

and then determining the three coefficients P, Q, R, so as to satisfy the three conditions

$$A' = 0, \quad . \quad . \quad (8.)$$

$$B' = 0, \quad . \quad . \quad (10.)$$

and

$$C' = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14.)$$

we should be conducted, by the law (5) of the composition of the coefficients A′, B′, C′, to a system of three equations, of the 1st, 2nd, and 3rd degrees, between the three coefficients P, Q, R; and consequently, by elimination, in general, to a final equation of the 6th degree, which the known methods are unable to resolve. Still less could we take away, in the present state of

algebra, *four terms* at once from the general equation of the m^{th} degree, or reduce it to the form

$$Y = y^m + E' y^{m-5} + \&c. = 0, \quad . \quad . \quad . \quad . \quad (15.)$$

by assuming an expression with four coefficients,

$$y = P + Q x + R x^2 + S x^3 + x^4 ; \quad . \quad . \quad . \quad (16.)$$

because the four conditions,

$$A' = 0, \quad . \quad . \quad (8.)$$
$$B' = 0, \quad . \quad . \quad (10.)$$
$$C' = 0, \quad . \quad . \quad (14.)$$

and

$$D' = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17.)$$

would be, with respect to these four coefficients, P, Q, R, S, of the 1st, 2nd, 3rd, and 4th degrees, and therefore would in general conduct by elimination to an equation of the 24th degree. In like manner, if we attempted to take away the 2nd, 3rd, and 5th terms (instead of the 2nd, 3rd, and 4th) from the general equation of the m^{th} degree, or to reduce it to the form

$$y^m + C' y^{m-3} + E' y^{m-5} + \&c. = 0, \quad . \quad . \quad . \quad (18.)$$

so as to satisfy the three conditions (8), (10) and (17),

$$A' = 0, \quad B' = 0, \quad D' = 0,$$

by assuming

$$y = P + Q x + R x^2 + x^3, \quad . \quad . \quad (13.)$$

we should be conducted to a final equation of the 8th degree; and if we attempted to satisfy these three other conditions

$$A' = 0, \quad . \quad . \quad (8.)$$
$$C' = 0, \quad . \quad . \quad (14.)$$

and

$$D' - \alpha B'^2 = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad (19.)$$

(in which α is any known or assumed number,) so as to transform the general equation (1) to the following,

$$Y = y^m + B' y^{m-2} + \alpha B'^2 y^{m-4} + E' y^{m-5} + \&c. = 0, \quad (20.)$$

by the same assumption (13), we should be conducted by elimination to an equation of condition of the 12th degree. It might, therefore, have been naturally supposed that each of these four transformations, (12), (15), (18), (20), of the equation of the m^{th} degree, was in general impossible to be effected in the present state of algebra. *Yet Mr. Jerrard has succeeded in effecting them all,* by suitable assumptions of the function y or $f(x)$, with-

out being obliged to resolve any equation higher than the fourth degree, and has even effected the transformation (12) without employing biquadratic equations. His method may be described as consisting in *rendering the problem indeterminate*, by assuming an expression for y with a number of disposable coefficients greater than the number of conditions to be satisfied; and in employing this indeterminateness to *decompose certain of the conditions* into others, for the purpose of *preventing that elevation of degree* which would otherwise result from the eliminations. This method is valid, in general, when the proposed equation is itself of a *sufficiently elevated degree*; but I have found that when the exponent m of that degree is *below a certain minor limit*, which is different for different transformations, (being $= 5$ for the first, $= 10$ for the second, $= 5$ for the third, and $= 7$ for the fourth of those already designated as the transformations (12), (15), (18) and (20),) the processes proposed by Mr. Jerrard conduct in general to an expression for the new variable y which is *a multiple of the proposed evanescent polynome* X of the m^{th} degree in x; and that on this account these processes, although *valid as general transformations of the equation of the* m^{th} *degree*, become in general *illusory* when they are applied to *resolve equations of the fourth and fifth degrees*, by reducing them to the binomial form, or by reducing the equation of the fifth degree to the known solvible form of De Moivre. An analogous process, suggested by Mr. Jerrard, for *reducing the general equation of the sixth to that of the fifth degree*, and a more general method of the same kind for resólving equations of higher degrees, appear to me to be in general, for a similar reason, illusory. Admiring the great ingenuity and talent exhibited in Mr. Jerrard's researches, I come to this conclusion with regret, but believe that the following discussion will be thought to establish it sufficiently.

[2.] To begin with the transformation (12), or the taking away of the second, third and fourth terms at once from the general equation of the m^{th} degree, Mr. Jerrard effects this transformation by assuming generally an expression with *seven* terms,

$$y = f(x) = \text{A}' x^{\lambda'} + \text{A}'' x^{\lambda''} + \text{A}''' x^{\lambda'''} + \text{M}' x^{\mu'} + \text{M}'' x^{\mu''} + \text{M}''' x^{\mu'''} + \text{M}^{\text{IV}} x^{\mu^{\text{IV}}} \quad \ldots \ (21.)$$

the seven unequal exponents $\lambda'\ \lambda''\ \lambda'''\ \mu'\ \mu''\ \mu'''\ \mu^{\text{IV}}$ being chosen at pleasure out of the indefinite line of integers

$$0,\ 1,\ 2,\ 3,\ 4,\ \&c. \quad \ldots\ldots\ldots \quad (22.)$$

and the seven coefficients $\text{A}'\ \text{A}''\ \text{A}'''\ \text{M}'\ \text{M}''\ \text{M}'''\ \text{M}^{\text{IV}}$, or rather their six ratios

$$\frac{\text{A}'}{\text{A}'''},\ \frac{\text{A}''}{\text{A}'''},\ \frac{\text{M}'}{\text{M}^{\text{IV}}},\ \frac{\text{M}''}{\text{M}^{\text{IV}}},\ \frac{\text{M}'''}{\text{M}^{\text{IV}}},\ \frac{\text{A}'''}{\text{M}^{\text{IV}}} \quad . \quad . \quad . \quad . \quad (23.)$$

being determined so as to satisfy the three conditions

$$\text{A}' = 0, \quad . \quad . \quad . \quad (8.)$$

$$\text{B}' = 0, \quad . \quad . \quad . \quad (10.)$$

$$\text{C}' = 0, \quad . \quad . \quad . \quad (14.)$$

without resolving any equation higher than the third degree, by a process which may be presented as follows.

In virtue of the assumption (21) and of the law (5) of the composition of the coefficients A′, B′, C′, it is easy to perceive that those three coefficients are rational and integral and homogeneous functions of the seven quantities A′ A″ A‴ M′ M″ M‴ M^{IV}, of the dimensions one, two, and three respectively; and therefore that A′ and B′ may be developed or decomposed into parts as follows:

$$\text{A}' = \text{A}'_{1,0} + \text{A}'_{0,1}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (24.)$$

$$\text{B} = \text{B}'_{2,0} + \text{B}'_{1,1} + \text{B}'_{0,2}, \quad . \quad . \quad . \quad . \quad (25.)$$

the symbol $\text{A}'_{h,i}$ or $\text{B}'_{h,i}$ denoting here a rational and integral function of A′, A″, A‴, M′, M″, M‴, M^{IV}, which is homogeneous of the degree h with respect to A′, A″, A‴, and of the degree i with respect to M′, M″, M‴, M^{IV}. If then we first determine the two ratios of A′, A″, A‴, so as to satisfy the two conditions

$$\text{A}'_{1,0} = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26.)$$

$$\text{B}'_{2,0} = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27.)$$

and afterwards determine the three ratios of M′, M″, M‴, M^{IV}, so as to satisfy the three other conditions

$$\text{A}'_{0,1} = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (28.)$$

$$\text{B}'_{1,1} = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (29.)$$

$$\text{B}'_{0,2} = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (30.)$$

we shall have decomposed the two conditions (8) and (10), namely,

$$\text{A}' = 0, \quad \text{B}' = 0,$$

into five others, and shall have satisfied these five by means of the five first ratios of the set (23), namely

$$\frac{\text{A}'}{\text{A}'''},\ \frac{\text{A}''}{\text{A}'''},\ \frac{\text{M}'}{\text{M}^{\text{IV}}},\ \frac{\text{M}''}{\text{M}^{\text{IV}}},\ \frac{\text{M}'''}{\text{M}^{\text{IV}}}, \quad . \quad . \quad . \quad . \quad . \quad (31.)$$

without having yet determined the remaining ratio of that set, namely

$$\frac{\Lambda'''}{\text{M}^{\text{IV}}}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (32.)$$

which remaining ratio can then in general be chosen so as to satisfy the remaining condition

$$C' = 0,$$

without our being obliged, in any part of the process, to resolve any equation higher than the third degree. And such, in substance, is Mr. Jerrard's general process for taking away the second, third, and fourth terms at once from the equation of the m^{th} degree, although he has expressed it in his published Researches by means of a new and elegant *notation of symmetric functions*, which it has not seemed necessary here to introduce, because the argument itself can be sufficiently understood without it.

[3.] On considering this process with attention, we perceive that it consists essentially of two principal parts, the one conducting to an expression of the form

$$y = f(x) = \Lambda''' \phi(x) + \text{M}^{\text{IV}} \chi(x), \quad . \quad . \quad . \quad (33.)$$

which satisfies the two conditions

$$A = 0, \quad B' = 0,$$

the functions $\phi(x)$ and $\chi(x)$ being determined, namely,

$$\phi(x) = \frac{\Lambda'}{\Lambda'''} x^{\lambda'} + \frac{\Lambda''}{\Lambda'''} x^{\lambda''} + x^{\lambda'''}, \quad . \quad . \quad . \quad (34.)$$

and

$$\chi(x) = \frac{\text{M}'}{\text{M}^{\text{IV}}} x^{\mu'} + \frac{\text{M}''}{\text{M}^{\text{IV}}} x^{\mu''} + \frac{\text{M}'''}{\text{M}^{\text{IV}}} x^{\mu'''} + x^{\mu^{\text{IV}}}, \quad .. \quad (35.)$$

but the multipliers Λ''' and M^{IV} being arbitrary, and the other part of the process determining afterwards the ratio of those two multipliers so as to satisfy the remaining condition

$$C' = 0.$$

And hence it is easy to see that if we would exclude those useless cases in which the ultimate expression for the new variable y, or for the function $f(x)$, is a multiple of the proposed evanescent polynome X of the m^{th} degree in x, we must, in general, exclude the cases in which the two functions $\phi(x)$ and $\chi(x)$, determined in the first part of the process, are connected by a relation of the form

$$\chi(x) = a\,\phi(x) + \lambda\,\text{X}, \quad . \quad . \quad . \quad . \quad . \quad (36.)$$

a being any constant multiplier, and $\lambda\,\text{X}$ any multiple of X.

For in all such cases the expression (33), obtained by the first part of the process, becomes

$$y = f(x) = (\Lambda''' + a\,\mathrm{M}^{\mathrm{IV}})\,\phi(x) + \lambda\,\mathrm{M}^{\mathrm{IV}}\,\mathrm{X}\,; \quad . \; . \quad (37.)$$

and since this gives, by the nature of the roots $x_1, \ldots x_m$,

$$f(x_1) = (\Lambda''' + a\,\mathrm{M}^{\mathrm{IV}})\,\phi(x_1), \; \ldots f(x_m) = (\Lambda''' + a\,\mathrm{M}^{\mathrm{IV}})\,\phi(x_m), \quad (38.)$$

we find, by the law (5) of the composition of the coefficients of the transformed equation in y,

$$\mathrm{C}' = c\,(\Lambda''' + a\,\mathrm{M}^{\mathrm{IV}})^3, \quad . \; . \; . \; . \; . \; . \quad (39.)$$

the multiplier c being known, namely,

$$c = -\,\phi(x_1)\,\phi(x_2)\,\phi(x_3) - \phi(x_1)\,\phi(x_2)\,\phi(x_4) - \&c. \quad (40.)$$

and being in general different from 0, because the three first of the seven terms of the expression (21) for y can only accidentally suffice to resolve the original problem; so that when we come, in the second part of the process, to satisfy the condition

$$\mathrm{C}' = 0,$$

we shall, in general, be obliged to assume

$$(\Lambda''' + a\,\mathrm{M}^{\mathrm{IV}})^3 = 0, \quad . \; . \; . \; . \; . \; . \quad (41.)$$

that is,

$$\Lambda''' + a\,\mathrm{M}^{\mathrm{IV}} = 0\,; \quad . \; . \; . \; . \; . \; . \quad (42.)$$

and consequently the expression (37) for y reduces itself ultimately to the form which we wished to exclude, since it becomes

$$y = \lambda\,\mathrm{M}^{\mathrm{IV}}\,\mathrm{X}. \quad . \; . \; . \; . \; . \; . \quad (43.)$$

Reciprocally, it is clear that the second part of the process, or the determination of the ratio of Λ''' to M^{IV} in the expression (33), cannot conduct to this useless form for y unless the two functions $\phi(x)$ and $\chi(x)$ are connected by a relation of the kind (36); because, when we equate the expression (33) to any multiple of X, we establish thereby a relation of that kind between those two functions. We must therefore endeavour to avoid those cases, and we need avoid those only, which conduct to this relation (36), and we may do so in the following manner.

[4.] Whatever positive integer the exponent ν may be, the power x^ν may always be identically equated to an expression of this form,

$$x^\nu = s_0^{(\nu)} + s_1^{(\nu)}\,x + s_2^{(\nu)}\,x^2 + \ldots + s_{m-1}^{(\nu)}\,x^{m-1} + \mathrm{L}^{(\nu)}\,\mathrm{X}, \quad (44.)$$

$s_0^{(\nu)}, s_1^{(\nu)}, s_2^{(\nu)}, \ldots s_{m-1}^{(\nu)}$ being certain functions of the exponent ν, and of the coefficients A, B, C, ... of the proposed po-

lynome X, while $L^{(\nu)}$ is a rational and integral function of x, which is $= 0$ if ν be less than the exponent m of the degree of that proposed polynome X, but otherwise is of the degree $\nu - m$. In fact, if we divide the power x^ν by the polynome X, according to the usual rules of the integral division of polynomes, so as to obtain an integral quotient and an integral remainder, the integral quotient may be denoted by $L^{(\nu)}$, and the integral remainder may be denoted by

$$s_0^{(\nu)} + s_1^{(\nu)} x + s_2^{(\nu)} x^2 + \dots + s_{m-1}^{(\nu)} x^{m-1},$$

and thus the identity (44) may be established. It may be noticed that the m coefficients $s_0^{(\nu)}, s_1^{(\nu)}, \dots s_{m-1}^{(\nu)}$, may be considered as symmetric functions of the m roots $x_1, x_2, \dots x_m$ of the proposed equation $X = 0$, which may be determined by the m relations,

$$\left.\begin{aligned} x_1^\nu &= s_0^{(\nu)} + s_1^{(\nu)} x_1 + s_2^{(\nu)} x_1^2 + \dots + s_{m-1}^{(\nu)} x_1^{m-1}, \\ x_2^\nu &= s_0^{(\nu)} + s_1^{(\nu)} x_2 + s_2^{(\nu)} x_2^2 + \dots + s_{m-1}^{(\nu)} x_2^{m-1}, \\ &\dots\dots \\ x_m^\nu &= s_0^{(\nu)} + s_1^{(\nu)} x_m + s_2^{(\nu)} x_m^2 + \dots + s_{m-1}^{(\nu)} x_m^{m-1}. \end{aligned}\right\} \quad (45.)$$

These symmetric functions of the roots possess many other important properties, but it is unnecessary here to develop them.

Adopting the notation (44), we may put, for abridgement,

$$\left.\begin{aligned} \Lambda' s_0^{(\lambda')} + \Lambda'' s_0^{(\lambda'')} + \Lambda''' s_0^{(\lambda''')} &= p_0, \\ \dots\dots\dots\dots \\ \Lambda' s_{m-1}^{(\lambda')} + \Lambda'' s_{m-1}^{(\lambda'')} + \Lambda''' s_{m-1}^{(\lambda''')} &= p'_{m-1}, \end{aligned}\right\} \quad \dots (46.)$$

$$\left.\begin{aligned} M' s_0^{(\mu')} + M'' s_0^{(\mu'')} + M''' s_0^{(\mu''')} + M^{IV} s_0^{(\mu^{IV})} &= p'_0, \\ \dots\dots\dots\dots \\ M' s_{m-1}^{(\mu')} + M'' s_{m-1}^{(\mu'')} + M''' s_{m-1}^{(\mu''')} + M^{IV} s_{m-1}^{(\mu^{IV})} &= p'_{m-1}, \end{aligned}\right\} (47.)$$

$$\Lambda' L^{(\lambda')} + \Lambda'' L^{(\lambda'')} + \Lambda''' L^{(\lambda''')} = \Lambda, \quad \dots \quad (48.)$$

$$M' L^{(\mu')} + M'' L^{(\mu'')} + M''' L^{(\mu''')} + M^{IV} L^{(\mu^{IV})} = M, \quad (49.)$$

$$\mathrm{\Lambda} + \mathrm{M} = \mathrm{L} \quad \ldots \quad (50.)$$

and then the two parts, of which the expression for y is composed, will take the forms

$$\left.\begin{array}{l} \mathrm{\Lambda}' x^{\lambda'} + \mathrm{\Lambda}'' x^{\lambda''} + \mathrm{\Lambda}''' x^{\lambda'''} = p_0 + p_1 x \\ \quad + \ldots + p_{m-1} x^{m-1} + \mathrm{\Lambda}\,\mathrm{X}, \end{array}\right\} \quad \ldots \quad (51.)$$

$$\left.\begin{array}{l} \mathrm{M}' x^{\mu'} + \mathrm{M}'' x^{\mu''} + \mathrm{M}''' x^{\mu'''} + \mathrm{M}^{\mathrm{IV}} x^{\mu^{\mathrm{IV}}} = p'_0 + p'_1 x \\ \quad + \ldots + p'_{m-1} x^{m-1} + \mathrm{M}\,\mathrm{X}, \end{array}\right\} \ldots (52.)$$

and the expression itself will become

$$\left.\begin{array}{l} y = f(x) = p_0 + p_0 + (p_1 + p'_1) x \\ \quad + \ldots + (p_{m-1} + p'_{m-1}) x^{m-1} \ \mathrm{L}\,\mathrm{X}. \end{array}\right\} \ldots (53.)$$

At the same time we see that the case to be avoided, for the reason lately assigned, is the case of proportionality of $p'_0, p'_1, \ldots p'_{m-1}$, to $p_0, p_1, \ldots p_{m-1}$. It is therefore convenient to introduce these new abbreviations,

$$\frac{p'_{m-1}}{p_{m-1}} = p, \quad \ldots \quad (54.)$$

and

$$p'_0 - p\,p_0 = q_0,\ p'_1 - p\,p_1 = q_1, \cdots p'_{m-2} - p\,p_{m-2} = q_{m-2}; \quad (55.)$$

for thus we obtain the expressions

$$\left.\begin{array}{l} p'_0 = q_0 + p\,p_0,\ p'_1 = q_1 + p\,p_1, \cdots p'_{m-2} \\ \quad = q_{m-2} + p\,p_{m-2},\ p'_{m-1} = p\,p_{m-1}, \end{array}\right\} \cdots (56.)$$

and

$$\left.\begin{array}{l} y = f(x) = (1 + p)\,(p_0 + p_1 x + \cdots p_{m-1} x^{m-1}) \\ \quad + q_0 + q_1 x + \ldots + q_{m-2} x^{m-2} + \mathrm{L}\,\mathrm{X}; \end{array}\right\} \ldots (57.)$$

and we have only to take care that the $m-1$ quantities, $q_0, q_1, \cdots q_{m-2}$ shall not all vanish. Indeed, it is tacitly supposed in (54) that p_{m-1} does not vanish; but it must be observed that Mr. Jerrard's method itself essentially supposes that the function $\mathrm{\Lambda}' x^{\lambda'} + \mathrm{\Lambda}'' x^{\lambda''} + \mathrm{\Lambda}''' x^{\lambda'''}$ is not any multiple of the evanescent polynome X, and therefore that *at least some one* of the m quantities $p_0, p_1, \cdots p_{m-1}$ is different from 0; now the spirit of the definitional assumptions here made, and of

the reasonings which are to be founded upon them, requires only that *some one* such non-evanescent quantity p_i out of this set $p_0, p_1, \dots p_{m-1}$ should be made the denominator of a fraction like (54), $\frac{p'_i}{p_i} = p$, and that thus some one term $q_i x^i$ should be taken away out of the difference of the two polynomes $p'_0 + p'_1 x + \dots$ and $p(p_0 x + p_1 x + \dots)$; and it is so easy to make this adaptation, whenever the occasion may arise, that I shall retain in the present discussion, the asssumptions (54) (55), instead of writing p_i for p_{m-1}.

The expression (57) for $f(x)$, combined with the law (5) of the composition of the coefficients A′ and B′, shows that these two coefficients of the transformed equation in y may be expressed as follows,

$$A' = (1+p)\,A''_{1,0} + A''_{0,1}, \quad \dots \dots \quad (58.)$$

and

$$B' = (1+p)^2\,B''_{2,0} + (1+p)\,B''_{1,1} + B''_{0,2}; \quad \dots \quad (59.)$$

$A''_{h,i}$ and $B''_{h,i}$ being each a rational and integral function of the $2m-1$ quantities $p_0, p_1, \dots p_{m-1}, q_0, q_1, \dots q_{m-2}$, which is independent of the quantity p and of the form of the function L, and is homogeneous of the dimension h with respect to $p_0, p_1, \dots p_{m-1}$, and of the dimension i with respect to $q_0, q_1, \dots q_{m-2}$. Comparing these expressions (58) and (59) with the analogous expressions (24) and (25), (with which they would of necessity identically coincide, if we were to return from the present to the former symbols, by substituting, for $p, p_0, p_1, \dots p_{m-1}, \dots q_0, q_1, \dots q_{m-2}$, their values as functions of A′, A″ A‴, M′, M″, M‴, M^IV, deduced from the equations of definition (54) (55) and (46) (47),) we find these identical equations:

$$A'_{1,0} = A''_{1,0};\ A'_{0,1} = p\,A''_{1,0} + A''_{0,1}; \quad \dots \quad (60.)$$

and

$$\left.\begin{aligned} B'_{2,0} = B''_{2,0};\ B'_{1,1} = 2p\,B''_{2,0} + B''_{1,1};\ B'_{0,2} \\ = p^2\,B''_{2,0} + p\,B''_{1,1} + B''_{0,2}; \end{aligned}\right\} \quad \dots \quad (61.)$$

observing that whatever may be the dimension of any part of A′ or B′, with respect to the m new quantities $p, q_0, q_1, \dots q_{m-2}$, the same is the dimension of that part, with respect to the four old quantities M′, M″, M‴, M^IV.

The system of the five conditions (26) (27) (28) (29) (30) may therefore be transformed to the following system,

$$A''_{1,0} = 0, \ B''_{2,0} = 0, \quad \ldots \ldots \quad (62.)$$

$$A''_{0,1} = 0, \ B''_{1,1} = 0, \ B''_{0,2} = 0 ; \quad \ldots \quad (63.)$$

and may in general be treated as follows. The two conditions (62), combined with the m equations of definition (46), will in general determine the $m+2$ ratios of the $m+3$ quantities $p_0, p_1, \ldots p_{m-1}$, A', A'', A'''; and then the three conditions (63), combined with the m equations of definition (47), and with the m other equations (56), will in general determine the $2m+3$ ratios of the $2m+4$ quantities $q_0, q_1, \ldots q_{m-2}, p\,p_{m-1}, p'_0, p'_1, \ldots p'_{m-1}$, M′, M″, M‴, M^{IV}; after which, the ratio of A''' to M^{IV} is to be determined, as before, so as to satisfy the remaining condition $\text{C}' = 0$. But because the last-mentioned system, of $2m+3$ homogeneous equations, (63) (56) (47), between $2m+4$ quantities, involves, as a part of itself, the system (63) of *three homogeneous equations* (rational and integral) *between* $m-1$ *quantities*, $q_0, q_1, \ldots q_{m-2}$, we see that it will in general conduct to the result which we wished to exclude, namely, the simultaneous vanishing of all those quantities,

$$q_0 = 0, \quad q_1 = 0, \ldots q_{m-2} = 0, \quad \ldots \quad (64.)$$

unless their number $m-1$ *be greater than* 3, that is, *unless the degree m of the proposed equation* (1) *be at least equal to the minor limit* FIVE. It results, then, from this discussion, that *the transformation by which Mr. Jerrard has succeeded in taking away three terms at once from the general equation of the* m^{th} *degree, is not in general applicable when that degree is lower than the 5th*; in such a manner that it is in general inadequate to reduce the biquadratic equation

$$x^4 + \text{A}\,x^3 + \text{B}\,x^2 + \text{C}\,x^3 + \text{D} = 0, \quad \ldots \quad (65.)$$

to the binomial form

$$y^4 + \text{D}' = 0, \quad \ldots \ldots \quad (66.)$$

except by the useless assumption

$$y = \text{L}\,(x^4 + \text{A}\,x^3 + \text{B}\,x^2 + \text{C}\,x^3 + \text{D}), \quad \ldots \quad (67.)$$

which gives

$$y^4 = 0. \quad \ldots \ldots \quad (68.)$$

However, the foregoing discussion may be considered as *confirming the adequacy of the method to reduce the general equation of the 5th degree,*

$$x^5 + \text{A}\,x^4 + \text{B}\,x^3 + \text{C}\,x^2 + \text{D}\,x + \text{E} = 0, \quad (69.)$$

to the trinomial form

$$y^5 + D'y + E' = 0; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (70.)$$

and to effect the analogous transformation (12) *for equations of all higher degrees*: an unexpected and remarkable result, which is one of Mr. Jerrard's principal discoveries.

[5.] Analogous remarks apply to the process proposed by the same mathematician for taking away the second, third and fifth terms at once from the general equation (1), so as to reduce that equation to the form (18). This process agrees with the foregoing in the whole of its first part, that is, in the assumption of the form (21) for $f(x)$, and in the determination of the five ratios (31) so as to satisfy the two conditions $A' = 0$, $B' = 0$, by satisfying the five others (26) (27) (28) (29) (30), into which those two may be decomposed; and the difference is only in the second part of the process, that is, in determining the remaining ratio (32) so as to satisfy the condition $D' = 0$, instead of the condition $C' = 0$, by resolving a biquadratic instead of a cubic equation. The discussion which has been given of the former process of transformation adapts itself therefore, with scarcely any change, to the latter process also, and shows that this process can only be applied with success, in general, to equations of the fifth and higher degrees. It is, however, a remarkable result that it can be applied generally to such equations, and especially that the general equation of the fifth degree may be brought by it to the following trinomial form,

$$y^5 + C'y^2 + E' = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad (71.)$$

as it was reduced, by the former process, to the form

$$y^5 + D'y + E' = 0. \quad . \quad . \quad (70.)$$

Mr. Jerrard, to whom the discovery of these transformations is due, has remarked that by changing y to $\frac{1}{z}$ we get two other trinomial forms to which *the general equation of the fifth degree* may be reduced; so that, *in any future researches respecting the solution of such equations, it will be permitted to set out with any one of these four trinomial forms,*

$$\left.\begin{array}{l} x^5 + A\,x^4 + E = 0, \\ x^5 + B\,x^3 + E = 0, \\ x^5 + C\,x^2 + E = 0, \\ x^5 + D\,x \;\; + E = 0, \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (72.)$$

in which the intermediate coefficient A or B or C or D may evidently be made equal to unity, or to any other assumed number different from zero. We may, for example, consider the difficulty of resolving the *general* equation of the fifth degree as re-

duced by Mr. Jerrard's researches to the difficulty of resolving an equation of the form

$$x^5 + x + E = 0; \quad . \quad . \quad . \quad . \quad . \quad . \quad (73.)$$

or of this other form,

$$x^5 - x + E = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (74.)$$

It is, however, important to remark that the coefficients of these new or transformed equations will often be imaginary, even when the coefficients of the original equation of the form (69) are real.

[6.] In order to accomplish the transformation (20), (to the consideration of which we shall next proceed,) Mr. Jerrard assumes, in general, an expression with *twelve* terms,

$$\left.\begin{array}{l} y = f(x) = \mathrm{A}' x^{\lambda'} + \mathrm{A}'' x^{\lambda''} + \mathrm{A}''' x^{\lambda'''} \\ \quad + \mathrm{M}' x^{\mu'} + \mathrm{M}'' x^{\mu''} + \mathrm{M}''' x^{\mu'''} + \mathrm{M}^{\mathrm{IV}} x^{\mu^{\mathrm{IV}}} \\ \quad + \mathrm{N}' x^{\nu'} + \mathrm{N}'' x^{\nu''} + \mathrm{N}''' x^{\nu'''} + \mathrm{N}^{\mathrm{IV}} x^{\nu^{\mathrm{IV}}} + \mathrm{N}^{\mathrm{V}} x^{\nu^{\mathrm{V}}}; \end{array}\right\} (75.)$$

the twelve unequal exponents,

$$\lambda', \lambda'', \lambda''', \mu', \mu'', \mu''', \mu^{\mathrm{IV}}, \nu', \nu'', \nu''', \nu^{\mathrm{IV}}, \nu^{\mathrm{V}}, \quad . \quad . \quad . \quad (76.)$$

being chosen at pleasure out of the indefinite line of integers (22); and the twelve coefficients,

$$\mathrm{A}', \mathrm{A}'', \mathrm{A}''', \mathrm{M}', \mathrm{M}'', \mathrm{M}''', \mathrm{M}^{\mathrm{IV}}, \mathrm{N}', \mathrm{N}'', \mathrm{N}''', \mathrm{N}^{\mathrm{IV}}, \mathrm{N}^{\mathrm{V}}, \quad (77.)$$

or rather their eleven ratios, which may be arranged and grouped as follows,

$$\frac{\mathrm{A}'}{\mathrm{A}'''}, \frac{\mathrm{A}''}{\mathrm{A}'''}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (78.)$$

$$\frac{\mathrm{M}'}{\mathrm{M}^{\mathrm{IV}}}, \frac{\mathrm{M}''}{\mathrm{M}^{\mathrm{IV}}}, \frac{\mathrm{M}'''}{\mathrm{M}^{\mathrm{IV}}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (79.)$$

$$\frac{\mathrm{N}'}{\mathrm{N}^{\mathrm{V}}}, \frac{\mathrm{N}''}{\mathrm{N}^{\mathrm{V}}}, \frac{\mathrm{N}'''}{\mathrm{N}^{\mathrm{V}}}, \frac{\mathrm{N}^{\mathrm{IV}}}{\mathrm{N}^{\mathrm{V}}}, \quad . \quad . \quad . \quad . \quad . \quad (80.)$$

$$\frac{\mathrm{M}^{\mathrm{IV}}}{\mathrm{N}^{\mathrm{V}}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (81.)$$

$$\frac{\mathrm{A}'''}{\mathrm{N}^{\mathrm{V}}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (82.)$$

being then determined so as to satisfy the system of the three conditions

$$\mathrm{A}' = 0, \quad . \quad . \quad (8.)$$

$$\mathrm{C}' = 0, \quad . \quad . \quad (14.)$$

$$\mathrm{D}' - \alpha \mathrm{B}'^2 = 0, \quad (19.)$$

by satisfying another system, composed of eleven equations, which are obtained by decomposing the condition (8) into three, and the condition (14) into seven new equations, as follows. By the law (5) of the formation of the four coefficients A', B', C', D', and by the assumed expression (75), those four coefficients are rational and integral and homogeneous functions, of the first, second, third, and fourth degrees, of the twelve coefficients (77); and therefore, when these latter coefficients are distributed into three groups, one group containing A', A'', A''', another group containing M', M'', M''', M^{IV}, and the third group containing N', N'', N''', N^{IV}, N^{V}, the coefficient or function A' may be decomposed into three parts,

$$A' = A'_{1,0,0} + A'_{0,1,0} + A'_{0,0,1}, \quad . \quad . \quad . \quad . \quad (83.)$$

and the coefficient or function C' may be decomposed in like manner into ten parts,

$$\left.\begin{aligned} C' = C'_{3,0,0} &+ C'_{2,1,0} + C'_{2,0,1} \\ &+ C'_{1,2,0} + C'_{1,1,1} + C'_{1,0,2} \\ &+ C'_{0,3,0} + C'_{0,2,1} + C'_{0,1,2} + C'_{0,0,3}, \end{aligned}\right\} \quad . \quad . \quad . \quad (84.)$$

in which each of the symbols of the forms $A'_{h,i,k}$ and $C'_{h,i,k}$ denotes a rational and integral function of the twelve quantities (77); which function ($A'_{h,i,k}$ or $C'_{h,i,k}$) is also homogeneous of the dimension h with respect to the quantities A', A'', A''', of the dimension i with respect to the quantities M', M'', M''', M^{IV}, and of the dimension k with respect to the quantities N', N'', N''', N^{IV}, N^{V}. Accordingly Mr. Jerrard decomposes the conditions $A' = 0$ and $C' = 0$ into ten others, which may be thus arranged:

$$A'_{1,0,0} = 0, \ C'_{3,0,0} = 0; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (85.)$$

$$A'_{0,1,0} = 0, \ C'_{2,1,0} = 0, \ C'_{1,2,0} = 0; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (86.)$$

$$A'_{0,0,1} = 0, \ C'_{2,0,1} = 0, \ C'_{1,1,1} = 0, \ C'_{1,0,2} = 0; \quad . \quad . \quad (87.)$$

$$C'_{0,3,0} + C'_{0,2,1} + C'_{0,1,2} + C'_{0,0,3} = 0; \quad . \quad . \quad . \quad . \quad . \quad . \quad (88.)$$

nine of the thirteen parts of the expressions (83) and (84) being made to vanish separately, and the sum of the other four parts being also made to vanish. He then determines the two ratios (78), so as to satisfy the two conditions (85); the three ratios (79), so as to satisfy the three conditions (86); the four ratios (80), so as to satisfy the four conditions (87); and the ratio (81), so as to satisfy the condition (88); all which determinations can in general be successively effected, without its being

necessary to resolve any equation higher than the third degree. The first part of the process is now completed, that is, the two conditions (8) and (14),

$$A' = 0, \quad C' = 0,$$

are now both satisfied by an expression of the form

$$y = f(x) = \Lambda''' \phi(x) + N^{V} \chi(x), \quad \ldots \quad (89.)$$

which is analogous to (33), and in which the functions $\phi(x)$ and $\chi(x)$ are known, but the multipliers Λ''' and N^{V} are arbitrary; and the second and only remaining part of the process consists in determining the remaining ratio (82), of Λ''' to N^{V}, by resolving an equation of the fourth degree, so as to satisfy the remaining condition,

$$D' - \alpha B'^2 = 0. \quad \ldots \quad (19.)$$

[7.] Such, then, (the notation excepted,) is Mr. Jerrard's general process for reducing the equation of the m^{th} degree,

$$X = x^m + A x^{m-1} + B x^{m-2} + C x^{m-3} + D x^{m-4} + E x^{m-5} + \&c. = 0, \quad \ldots \quad (1.)$$

to the form

$$Y = y^m + B' y^{m-2} + \alpha B'^2 y^{m-4} + E' y^{m-5} + \&c. = 0, \quad (20.)$$

without resolving any auxiliary equation of a higher degree than the fourth. But, on considering this remarkable process with attention, we perceive that if we would avoid its becoming illusory, by conducting to an expression for y which is a multiple of the proposed polynome X, we must, in general, (for reasons analogous to those already explained in discussing the transformation (12),) exclude all those cases in which the functions $\phi(x)$ and $\chi(x)$, in the expression (89), are connected by a relation of the form

$$\chi(x) = a\,\phi(x) + \lambda X; \quad \ldots \quad (36.)$$

because, in all the cases in which such a relation exists, the first part of the process conducts to an expression of the form

$$y = (\Lambda''' + a N^{V}) \phi(x) + \lambda N^{V} X, \quad \ldots \quad (90.)$$

and then the second part of the same process gives in general

$$(\Lambda''' + a N^{V})^4 = 0, \quad \ldots \quad (91.)$$

that is

$$\Lambda''' + a N^{V} = 0, \quad \ldots \quad (92.)$$

and ultimately

$$y = \lambda N^{V} X. \quad \ldots \quad (93.)$$

On the other hand, the second part of the process cannot conduct to this useless form for y, unless the first part of the process has led to functions, $\phi(x)$, $\chi(x)$, connected by a relation of the form (36.). This consideration suggests the introduction of the following new system of equations of definition.

$$\left.\begin{array}{l} N' s_0^{(\nu')} + N'' s_0^{(\nu'')} + N''' s_0^{(\nu''')} + N^{IV} s_0^{(\nu^{IV})} + N^{V} s_0^{(\nu^{V})} \\ \qquad = p''_0, \\ \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ N' s^{(\nu')}_{m-1} + N'' s^{(\nu'')}_{m-1} + N''' s^{(\nu''')}_{m-1} + N^{IV} s^{(\nu^{IV})}_{m-1} + N^{V} s^{(\nu^{V})}_{m-1} \\ \qquad = p''_{m-1}, \end{array}\right\} \quad (94.)$$

$$N' L^{(\nu')} + N'' L^{(\nu'')} + N''' L^{(\nu''')} + N^{IV} L^{(\nu^{IV})} + N^{V} L^{(\nu^{V})} = N, \quad (95.)$$

$$\frac{p''_{m-1}}{p_{m-1}} = p', \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (96.)$$

$$\left.\begin{array}{l} p''_0 - p' p_0 = q'_0, \; p''_1 - p' p_1 = q'_1, \; \dots \; p''_{m-2} - p' p_{m-2} \\ \qquad = q'_{m-2} \end{array}\right\} (97.)$$

to be combined with the definitions (46), (47), (48), (49), (54), (55), and with the following, which may now be conveniently used instead of the definition (50),

$$\Lambda + M + N = L. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (98.)$$

In this notation we shall have, as before,

$$\left.\begin{array}{l} p'_0 = q_0 + p\,p_0, \; p'_1 = q_1 + p\,p_1, \; \dots p'_{m-2} = q_{m-2} \\ \qquad + p\,p_{m-2}, \; p'_{m-1} = p\,p_{m-1}, \end{array}\right\} \quad (56.)$$

and shall also have the analogous expressions

$$\left.\begin{array}{l} p''_0 = q'_0 + p' p_0, \; p''_1 = q'_1 + p' p_1, \; \dots p''_{m-2} = q'_{m-2} \\ \qquad + p' p_{m-2}, \; p''_{m-1} = p' p_{m-1}; \end{array}\right\} \quad (99.)$$

the expression (75) for y will become

$$\left.\begin{array}{l} y = f(x) = p_0 + p'_0 + p''_0 + (p_1 + p'_1 + p''_1)\,x + \dots \\ \qquad + (p_{m-1} + p'_{m-1} + p''_{m-1})\,x^{m-1} + L X, \end{array}\right\} \quad (100.)$$

that is, by (56) and (99),

$$\left.\begin{array}{l} y = f(x) = (1 + p + p')\,(p_0 + p_1 x + \dots + p_{m-1} x^{m-1}) \\ \qquad + q_0 + q'_0 + (q_1 + q'_1)\,x + \dots + (q_{m-2} + q'_{m-2})\,x^{m-2} \\ \qquad + L X: \end{array}\right\} (101.)$$

and the excluded case, or case of failure, will now be the case when the sums $p'_0 + p''_0, p'_1 + p''_1, \dots p'_{m-1} + p''_{m-1}$ are proportional to $p_0, p_1, \dots p_{m-1}$, that is, when

$$q_0 + q'_0 = 0, q_1 + q'_1 = 0, \dots q_{m-2} + q'_{m-2} = 0. \quad . \quad . \quad (102.)$$

Indeed, it is here tacitly supposed that p_{m-1} does not vanish; but Mr. Jerrard's method itself supposes tacitly that at least some one, such as p_i, of the m quantities $p_0, \dots p_{m-1}$, is different from 0, and it is easy, upon occasion, to substitute any such non-evanescent quantity p_i for p_{m-1}, and then to make the few other connected changes which the spirit of this discussion requires.

The expression (101) for $f(x)$, combined with the law (5) of the composition of the coefficients A′ and C′, gives, for those coefficients, expressions of the forms,

$$A' = (1 + p + p')\,A''_{1,0,0} + A''_{0,1,0} + A''_{0,0,1}, \quad . \quad . \quad . \quad . \quad (103.)$$

and

$$\left.\begin{aligned} C' = {} & (1+p+p')^3\,C''_{3,0,0} + (1+p+p')^2\,(C''_{2,1,0} + C''_{2,0,1}) \\ & + (1+p+p')\,(C''_{1,2,0} + C''_{1,1,1} + C''_{1,0,2}) \\ & + C''_{0,3,0} + C''_{0,2,1} + C''_{0,1,2} + C''_{0,0,3}, \end{aligned}\right\} (104.)$$

$A''_{h,i,k}$ and $C''_{h,i,k}$ being rational and integral functions of the $3m - 2$ quantities $p_0, p_1, \dots p_{m-1}, q_0, q_1, \dots q_{m-2}, q'_0, q'_1, \dots q'_{m-2}$, which functions are independent of p, p', and L, and are homogeneous of the dimension h with respect to $p_0, \dots p_{m-1}$, of the dimension i with respect to $q_0, \dots q_{m-2}$, and of the dimension k with respect to $q'_0, \dots q'_{m-2}$; they are also such that the sums

$$A''_{0,1,0} + A''_{0,0,1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (105.)$$

and

$$C''_{2,1,0} + C''_{2,0,1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (106.)$$

are homogeneous functions, of the 1st dimension, of the $m - 1$ sums $q_0 + q'_0, \dots q_{m-2} + q'_{m-2}$; while the sum

$$C''_{1,2,0} + C''_{1,1,1} + C''_{1,0,2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (107.)$$

is a homogeneous function, of the 2nd dimension, and the sum

$$C''_{0,3,0} + C''_{0,2,1} + C''_{0,1,2} + C''_{0,0,3} \quad . \quad . \quad . \quad . \quad (108.)$$

is a homogeneous function, of the 3rd dimension, of the same $m - 1$ quantities. These new expressions, (103) and (104), for

the coefficients A′ and C′, must identically coincide with the former expressions (83) and (84), when we return from the present to the former notation, by changing p, p', p_0, p_1, ... p_{m-1}, q_0, q_1, ... q_{m-2}, q'_0, q'_1, ... q'_{m-2}, to their values as functions of Λ', Λ'', Λ''', M', M'', M''', M^{IV}, N', N'', N''', N^{IV}, N^{V}; and hence it is easy to deduce the following identical equations:

$$\left.\begin{array}{l} A'_{1,0,0} = A''_{1,0,0}; \\ A'_{0,1,0} = p\,A''_{1,0,0} + A''_{0,1,0}; \\ A'_{0,0,1} = p'\,A''_{1,0,0} + A''_{0,0,1}; \end{array}\right\} \quad \text{(109.)}$$

and

$$\left.\begin{array}{l} C'_{3,0,0} = C''_{3,0,0}; \\ C'_{2,1,0} = 3\,p\,C''_{3,0,0} + C''_{2,1,0}; \\ C'_{2,0,1} = 3\,p'\,C''_{3,0,0} + C''_{2,0,1}; \\ C'_{1,2,0} = 3\,p^2\,C''_{3,0,0} + 2\,p\,C''_{2,1,0} + C''_{1,2,0}; \\ C'_{1,1,1} = 6\,p\,p'\,C''_{3,0,0} + 2\,p'\,C''_{2,1,0} + 2\,p\,C''_{2,0,1} + C''_{1,1,1}; \\ C'_{1,0,2} = 3\,p'^2\,C''_{3,0,0} + 2\,p'\,C''_{2,0,1} + C''_{1,0,2}; \\ C'_{0,3,0} + C'_{0,2,1} + C'_{0,1,2} + C'_{0,0,3} = (p + p')^3\,C''_{3,0,0} \\ \quad + (p + p')^2\,(C''_{2,1,0} + C''_{2,0,1}) \\ \quad + (p + p')\,(C''_{1,2,0} + C''_{1,1,1} + C''_{1,0,2}) \\ \quad + C''_{0,3,0} + C''_{0,2,1} + C''_{0,1,2} + C''_{0,0,3}. \end{array}\right\} \quad \text{(110.)}$$

The system of the ten conditions (85), (86), (87), (88), may therefore be transformed to the following:

$$A''_{1,0,0} = 0, \; C''_{3,0,0} = 0; \quad \text{(111.)}$$

$$A''_{0,1,0} = 0, \; C''_{2,1,0} = 0, \; C''_{1,2,0} = 0; \quad \text{(112.)}$$

$$A''_{0,0,1} = 0, \; C''_{2,0,1} = 0, \; C''_{1,1,1} = 0, \; C''_{1,0,2} = 0; \quad \text{(113.)}$$

$$C''_{0,3,0} + C''_{0,2,1} + C''_{0,1,2} + C''_{0,0,3} = 0; \quad \text{(114.)}$$

and may in general be treated as follows. The two conditions (111) may first be combined with the m equations of definition (46), and employed to determine the $m + 2$ ratios of the $m + 3$ quantities p_0, ... p_{m-1}, Λ', Λ'', Λ'''; and therefore to give a result of the form

$$\Lambda'\,x^{\lambda'} + \Lambda''\,x^{\lambda''} + \Lambda'''\,x^{\lambda'''} = \Lambda'''\,\phi\,(x), \quad \text{(115.)}$$

the function $\phi\,(x)$ being known. The three conditions (112), combined with the $2\,m$ equations (47) and (56), may then be

used to determine the $2m+3$ ratios of the $2m+4$ quantities $q_0, \ldots q_{m-2}, p\, p_{m-1}, p'_0, \ldots p'_{m-1}, \mathrm{M}', \mathrm{M}'', \mathrm{M}''', \mathrm{M}^{\mathrm{IV}}$, and consequently to give

$$\mathrm{M}' x^{\mu'} + \mathrm{M}'' x^{\mu''} + \mathrm{M}''' x^{\mu'''} + \mathrm{M}^{\mathrm{IV}} x^{\mu^{\mathrm{IV}}} = \mathrm{M}^{\mathrm{IV}} \psi(x), \quad (116.)$$

$\psi(x)$ denoting a known function. The four conditions (113) may next be combined with the $2m$ equations (94) and (99), so as to determine the $2m+4$ ratios of the $2m+5$ quantities $q'_0, \ldots q'_{m-2}, p'\, p_{m-1}, p''_0, \ldots p''_{m-1}, \mathrm{N}', \mathrm{N}'', \mathrm{N}''', \mathrm{N}^{\mathrm{IV}}, \mathrm{N}^{\mathrm{V}}$; and thus we shall have

$$\mathrm{N}' x^{\nu'} + \mathrm{N}'' x^{\nu''} + \mathrm{N}''' x^{\nu'''} + \mathrm{N}^{\mathrm{IV}} x^{\nu^{\mathrm{IV}}} + \mathrm{N}^{\mathrm{V}} x^{\nu^{\mathrm{V}}} = \mathrm{N}^{\mathrm{V}} \omega(x), \quad (117.)$$

the function $\omega(x)$ also being known; so that, at this stage, the expression (75) for y will be reduced to the form

$$y = f(x) = \mathrm{\Lambda}''' \phi(x) + \mathrm{M}^{\mathrm{IV}} \psi(x) + \mathrm{N}^{\mathrm{V}} \omega(x), \quad . \; . \quad (118.)$$

the three functions $\phi(x)$, $\psi(x)$, $\omega(x)$ being known, but the three coefficients $\mathrm{\Lambda}'''$, M^{IV}, N^{V}, being arbitrary. The condition (114) will next determine the ratio of any one of the quantities $q_0, \ldots q_{m-2}$ to any one of the quantities $q'_0, \ldots q'_{m-2}$, and therefore also the connected ratio of M^{IV} to N^{V}, and consequently will give

$$\mathrm{M}^{\mathrm{IV}} \psi(x) + \mathrm{N}^{\mathrm{V}} \omega(x) = \mathrm{N}^{\mathrm{V}} \chi(x), \quad . \; . \; . \; . \quad (119.)$$

$\chi(x)$ being another known function; and thus we shall have accomplished, in a way apparently but not essentially different from that employed in the foregoing article, the first part of Mr. Jerrard's process, namely, the discovery of an expression for y, of the form

$$y = f(x) = \mathrm{\Lambda}''' \phi(x) + \mathrm{N}^{\mathrm{V}} \chi(x), \quad . \; . \; . \quad (89.)$$

which satisfies the two conditions

$$\mathrm{A}' = 0, \quad \mathrm{C}' = 0,$$

the functions $\phi(x)$ and $\chi(x)$ being determined and known, but the multipliers $\mathrm{\Lambda}'''$ and N^{V} being arbitrary: after which it will only remain to perform the second part of the process, namely, the determination of the ratio of $\mathrm{\Lambda}'''$ to N^{V}, so as to satisfy the remaining condition

$$\mathrm{D}' - \alpha \mathrm{B}'^2 = 0,$$

by resolving a biquadratic equation.

[8.] The advantage of this new way of presenting the first part of Mr. Jerrard's process is that it enables us to perceive, that if we would avoid the case of failure above mentioned, we must in general exclude those cases in which the ratios

$$\frac{q'_0}{q'_{m-2}}, \frac{q'_1}{q'_{m-2}}, \ldots \frac{q'_{m-3}}{q'_{m-2}}, \quad \ldots \ldots \quad (120.)$$

determined, as above explained, through the medium of the conditions (113), coincide with the ratios

$$\frac{q_0}{q_{m-2}}, \frac{q_1}{q_{m-2}}, \ldots \frac{q_{m-3}}{q_{m-2}}, \quad \ldots \ldots \quad (121.)$$

determined, at an earlier stage, through the medium of the conditions (112). In fact, when the ratios (120) coincide with the ratios (121), they necessarily coincide with the following ratios also,

$$\frac{q_0 + q'_0}{q_{m-2} + q'_{m-2}}, \frac{q_1 + q'_1}{q_{m-2} + q'_{m-2}}, \ldots \frac{q_{m-3} + q'_{m-3}}{q_{m-2} + q'_{m-2}}; \quad \ldots (122.)$$

and unless the ratios, thus determined, of the $m - 1$ sums $q_0 + q'_0, \ldots q_{m-2} + q'_{m-2}$, are accidentally such as to satisfy the condition (114), which had not been employed in determining them, then that condition, which is a rational and integral and homogeneous equation of the third degree between those quantities, will oblige them all to vanish, and therefore will conduct to the case of failure (102). Reciprocally, in that case of failure, the ratios (120) coincide with the ratios (121), because we have then

$$q'_0 = - q_0, \; q'_1 = - q_1, \ldots q'_{m-2} = - q_{m-2}. \quad \ldots (123.)$$

The case to be excluded, in general, is therefore that in which the $m - 1$ quantities $q'_0, \ldots q'_{m-2}$ are proportional to the $m - 1$ quantities $q_0, \ldots q_{m-2}$; and this consideration suggests the introduction of the following new symbols or definitions,

$$\frac{q'_{m-2}}{q_{m-2}} = q, \quad \ldots \ldots \quad (124.)$$

$$q'_0 - q\, q_0 = r_0, \; q'_1 - q\, q_1 = r_1, \ldots q'_{m-3} - q\, q_{m-3} = r_{m-3}; \quad (125.)$$

because, by introducing these, we shall only be obliged to guard against the simultaneous vanishing of the $m - 2$ quantities $r_0, r_1, \ldots r_{m-3}$; that is, we shall have the following simplified statement of the general case of failure,

$$r_0 = 0, \; r_1 = 0, \ldots r_{m-3} = 0. \quad \ldots \ldots \quad (126.)$$

Adopting, therefore, the definitions (124) and (125), and consequently the expressions

$$\left.\begin{array}{l} q'_0 = r_0 + q\, q_0,\ q'_1 = r_1 + q\, q_1, \cdots \\ q'_{m-3} = r_{m-3} + q\, q_{m-3},\ q'_{m-2} = q\, q_{m-2}, \end{array}\right\} \quad \text{(127.)}$$

which give

$$\left.\begin{array}{l} q_0 + q'_0 = (1+q)\, q_0 + r_0,\ q_1 + q'_1 = (1+q)\, q_1 + r_1, \cdots \\ q_{m-3} + q'_{m-3} = (1+q)\, q_{m-3} + r_{m-3},\ q_{m-2} + q'_{m-2} \\ \qquad = (1+q)\, q_{m-2}, \end{array}\right\} \text{(128.)}$$

we easily perceive that the three homogeneous functions (105) (106) (107), of these $m-1$ sums $q_0 + q'_0, \cdots q_{m-2} + q'_{m-2}$, may be expressed in the following manner:

$$A''_{0,1,0} + A''_{0,0,1} = (1+q)\, A'''_{0,1,0} + A'''_{0,0,1}\,; \quad \text{(129.)}$$

$$C''_{2,1,0} + C''_{2,0,1} = (1+q)\, C'''_{2,1,0} + C'''_{2,0,1}\,; \quad \text{(130.)}$$

$$\left.\begin{array}{l} C''_{1,2,0} + C''_{1,1,1} + C''_{1,0,2} = (1+q)^2\, C'''_{1,2,0} \\ \qquad + (1+q)\, C'''_{1,1,1} + C'''_{1,0,2}\,; \end{array}\right\} \quad \text{(131.)}$$

the symbol $A'''_{h,i,k}$ or $C'''_{h,i,k}$ denoting here a rational and integral function of the $3m-3$ quantities $p_0, \cdots p_{m-1}, q_0, \cdots q_{m-2}, r_0, \cdots r_{m-3}$, which is, like the function $A''_{h,i,k}$ or $C''_{h,i,k}$, homogeneous of the dimension h with respect to $p_0, \cdots p_{m-1}$, and of the dimension i with respect to $q_0, \cdots q_{m-2}$, but is homogeneous of the dimension k with respect to $r_0, \cdots r_{m-3}$, and is independent of $q'_0, \cdots q'_{m-2}$ and of p, p', q; whereas $A''_{h,i,k}$ or $C''_{h,i,k}$ was homogeneous of the dimension k with respect to $q'_0, \cdots q'_{m-2}$, and was independent of $r_0, \cdots r_{m-3}$. The three identical equations (129) (130) (131) may be decomposed into the seven following, which are analogous to (60) (and (61):

$$A''_{0,1,0} = A'''_{0,1,0}\,;\ A''_{0,0,1} = q\, A'''_{0,1,0} + A'''_{0,0,1}\,; \quad \text{(132.)}$$

$$C''_{2,1,0} = C'''_{2,1,0}\,;\ C''_{2,0,1} = q\, C'''_{2,1,0} + C'''_{2,0,1}\,; \quad \text{(133.)}$$

$$\left.\begin{array}{l} C''_{1,2,0} = C'''_{1,2,0}\,;\ C''_{1,1,1} = 2\, q\, C'''_{1,2,0} + C'''_{1,1,1}\,; \\ C''_{1,0,2} = q^2\, C'''_{1,2,0} + q\, C'''_{1,1,1} + C'''_{1,0,2}\,; \end{array}\right\} \quad \text{(134.)}$$

and, in virtue of these, the seven conditions (112) and (113) may be put under the forms,

$$A'''_{0,1,0} = 0,\ C'''_{2,1,0} = 0,\ C'''_{1,2,0} = 0, \quad \text{(135.)}$$

and

$$A'''_{0,0,1} = 0,\ C'''_{2,0,1} = 0,\ C'''_{1,1,1} = 0,\ C'''_{1,0,2} = 0. \quad \text{(136.)}$$

The three conditions of the group (135) differ only in their notation from the three conditions (112), and are to be used exactly like those former conditions, in order to determine the ratios of $q_0, \ldots q_{m-2}$, after the ratios of $p_0, \ldots p_{m-1}$ have been determined, through the help of the conditions (111); but, in deducing the conditions (136) from the conditions (113), a real simplification has been effected (and not merely a change of notation) by suppressing several terms, such as $q\,\mathrm{A}'''_{0,1,0}$, which vanish in consequence of the conditions (112) or (135). And since we have thus been led to perceive the existence of a group, (136), of four homogeneous equations (rational and integral) between the $m - 2$ quantities $r_0, r_1, \ldots r_{m-3}$, we see, at last, that we shall be conducted, in general, to the *case of failure* (126), in which all those quantities vanish, *unless their number* $m - 2$ *be greater than four*; that is, *unless the degree of the proposed equation in* x *be at least equal to the minor limit* SEVEN. It results, then, from this analysis, that for equations of the *sixth* and *lower* degrees, Mr. Jerrard's process for effecting the transformation (20), or for satisfying the three conditions (8) (14) and (19),

$$\mathrm{A}' = 0,\ \mathrm{C}' = 0,\ \mathrm{D}' - \alpha\,\mathrm{B}'^2 = 0,$$

will, in general, become *illusory*, by conducting to an useless expression, of the form (93), for the new variable y; so that it *fails*, for example, *to reduce the general equation of the fifth degree*,

$$x^5 + \mathrm{A}\,x^4 + \mathrm{B}\,x^3 + \mathrm{C}\,x^2 + \mathrm{D}\,x + \mathrm{E} = 0, \quad . \ . \ (69.)$$

to De Moivre's solvible form,

$$y^5 + \mathrm{B}'\,y^3 + \tfrac{1}{5}\,\mathrm{B}'^2\,y + \mathrm{E}' = 0, \quad . \ . \ . \ . \ (137.)$$

except, by an useless assumption, of the form

$$y = \mathrm{L}\,(x^5 + \mathrm{A}\,x^4 + \mathrm{B}\,x^3 + \mathrm{C}\,x^2 + \mathrm{D}\,x + \mathrm{E}), \quad . \ . \ (138.)$$

which gives, indeed, a very simple transformed equation, namely,

$$y^5 = 0, \quad . \ . \ . \ . \ . \ . \ . \ . \ (139.)$$

but affords no assistance whatever towards resolving the proposed equation in x. Indeed, for equations of the *fifth* degree, the foregoing discussion may be considerably simplified, by observing, that, in virtue of the eight conditions (112) (113) (114), the four homogeneous functions (105) (106) (107) (108), of the $m - 1$ sums $q_0 + q'_0, \ldots q_{m-2} + q'_{m-2}$, are all $= 0$, and therefore also (in general) those sums themselves must vanish (which is the case of failure (102),) when their number $m - 1$ is not

greater than four, that is, *when the proposed equation is not higher than the fifth degree.* But the foregoing discussion (though the great generality of the question has caused it to be rather long) has the advantage of extending even to equations of the *sixth* degree, and of showing that even for such equations the method generally fails, in such a manner that it will not in general reduce the equation

$$x^6 + \mathrm{A}\,x^5 + \mathrm{B}\,x^4 + \mathrm{C}\,x^3 + \mathrm{D}\,x^2 + \mathrm{E}\,x + \mathrm{F} = 0 \qquad (140.)$$

to the form

$$y^6 + \mathrm{B}'\,y^4 + \alpha\,\mathrm{B}'^2\,y^2 + \mathrm{E}'\,y + \mathrm{F}' = 0, \quad . \quad . \quad (141.)$$

except by the assumption

$$y = \mathrm{L}\,(x^6 + \mathrm{A}\,x^5 + \mathrm{B}\,x^4 + \mathrm{C}\,x^3 + \mathrm{D}\,x^2 + \mathrm{E}\,x + \mathrm{F})\,; \quad (142.)$$

which gives, indeed, a very simple result, namely,

$$y^6 = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (143.)$$

but does not at all assist us to resolve the proposed equation (140.). However, this discussion may be regarded as *confirming the adequacy of the method to transform the general equation of the seventh degree,*

$$x^7 + \mathrm{A}\,x^6 + \mathrm{B}\,x^5 + \mathrm{C}\,x^4 + \mathrm{D}\,x^3 + \mathrm{E}\,x^2 + \mathrm{F}\,x + \mathrm{G} = 0, \quad (144.)$$

to another of the form

$$y^7 + \mathrm{B}'\,y^5 + \alpha\,\mathrm{B}'^2\,y^3 + \mathrm{E}'\,y^2 + \mathrm{F}'\,y + \mathrm{G}' = 0, \quad . \quad . \quad (145.)$$

without assuming $y =$ any multiple of the proposed evanescent polynome $x^7 + \mathrm{A}\,x^6 +$ &c.; and to effect the analogous transformation (20), for equations of all *higher* degrees; a curious and unexpected discovery, for which algebra is indebted to Mr. Jerrard.

[9.] The result obtained by the foregoing discussion may seem, so far as it respects equations of the *sixth* degree, to be of very little importance; because the equation (141), to which it has been shown that the method fails to reduce the general equation (140), is not itself, in general, of any known solvible form, whatever value may be chosen for the arbitrary multiplier α. But it must be observed that if the method had in fact been adequate to effect that general transformation of the equation of the sixth degree, without resolving any auxiliary equation of a higher degree than the fourth, then it would also have been adequate to reduce the same general equation (140) of the sixth degree to this other form, which is obviously and easily solvible,

$$y^6 + \mathrm{B}'\,y^4 + \mathrm{D}'\,y^2 + \mathrm{F}' = 0, \quad . \quad . \quad . \quad . \quad . \quad (146.)$$

by first assigning an expression of the form

$$y = f(x) = \Lambda'''\,\phi\,(x) + \mathrm{N}^{\mathrm{V}}\,\chi\,(x), \quad . \quad . \quad (89.)$$

which should satisfy the two conditions

$$A' = 0, \quad . \quad . \quad . \quad (8.)$$

$$C' = 0, \quad . \quad . \quad . \quad (14.)$$

and by then determining the ratio of Λ''' to N^{V}, so as to satisfy this other condition,

$$E' = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (147.)$$

which could be done without resolving any auxiliary equation of a higher degree than the fifth; and this *reduction, of the difficulty of the sixth to that of the fifth degree*, would have been a very important result, of which it was interesting to examine the validity. The foregoing discussion, however, appears to me to prove that *this transformation also is illusory*; for it shows that, because the degree of the proposed equation is less than the minor limit 7, the functions $\phi(x)$ and $\chi(x)$ in (89) are connected by a relation of the form (36); on which account the expression (89) becomes

$$y = f(x) = (\Lambda''' + a\,N^{V})\,\phi(x) + \lambda\,N^{V}\,X, \quad . \quad . \quad (90.)$$

and the condition

$$E' = 0, \quad . \quad . \quad (147.)$$

gives, in general,

$$(\Lambda''' + a\,N^{V})^5 = 0, \quad . \quad . \quad . \quad . \quad . \quad (148.)$$

that is,

$$\Lambda''' + a\,N^{V} = 0; \quad . \quad . \quad (92.)$$

so that finally the expression for y becomes

$$y = \lambda\,N^{V}\,X, \quad . \quad . \quad . \quad . \quad (93.)$$

that is, it takes in general the evidently useless form,

$$y = L\,(x^6 + A\,x^5 + B\,x^4 + C\,x^3 + D\,x^2 + E\,x + F). \quad (142.)$$

[10.] Mr. Jerrard has not actually stated, in his published Researches, the process by which he would effect in general the transformation (15), so as to *take away four terms* at once from the equation of the m^{th} degree, without resolving any auxiliary equation of a higher degree than the fourth; but he has sufficiently indicated this process, which appears to be such as the following. He would probably assume an expression with *twenty-one* terms for the new variable,

$$\left.\begin{aligned} y = f(x) = {} & \Lambda'\,x^{\lambda'} + \Lambda''\,x^{\lambda''} + \Lambda'''\,x^{\lambda'''} \\ & + M'\,x^{\mu'} + M''\,x^{\mu''} + M'''\,x^{\mu'''} + M^{IV}\,x^{\mu^{IV}} \\ & + N'\,x^{\nu'} + N''\,x^{\nu''} + N'''\,x^{\nu'''} + N^{IV}\,x^{\nu^{IV}} \\ & + N^{V}\,x^{\nu^{V}} + N^{VI}\,x^{\nu^{VI}} \\ & + \Xi'\,x^{\xi'} + \Xi''\,x^{\xi''} + \Xi'''\,x^{\xi'''} + \Xi^{IV}\,x^{\xi^{IV}} + \Xi^{V}\,x^{\xi^{V}} \\ & + \Xi^{VI}\,x^{\xi^{VI}} + \Xi^{VII}\,x^{\xi^{VII}} + \Xi^{VIII}\,x^{\xi^{VIII}}, \end{aligned}\right\} \quad (149.)$$

and would develop or decompose the coefficients A′, B′, C′, of the transformed equation in y, considered as rational and integral and homogeneous functions of the twenty-one coefficients,

$$\Lambda', \Lambda'', \Lambda''', \quad \ldots \quad (150.)$$
$$\mathrm{M}', \mathrm{M}'', \mathrm{M}''', \mathrm{M}^{\mathrm{IV}}, \quad \ldots \quad (151.)$$
$$\mathrm{N}', \mathrm{N}'', \mathrm{N}''', \mathrm{N}^{\mathrm{IV}}, \mathrm{N}^{\mathrm{V}}, \mathrm{N}^{\mathrm{VI}}, \quad \ldots \quad (152.)$$
$$\Xi', \Xi'', \Xi''', \Xi^{\mathrm{IV}}, \Xi^{\mathrm{V}}, \Xi^{\mathrm{VI}}, \Xi^{\mathrm{VII}}, \Xi^{\mathrm{VIII}}, \quad \ldots \quad (153.)$$

into the following parts:

$$\mathrm{A}' = \mathrm{A}'_{1,0,0,0} + \mathrm{A}'_{0,1,0,0} + \mathrm{A}'_{0,0,1,0} + \mathrm{A}'_{0,0,0,1}; \quad \ldots \quad (154.)$$

$$\left.\begin{aligned} \mathrm{B}' = \mathrm{B}'_{2,0,0,0} &+ \mathrm{B}'_{1,1,0,0} + \mathrm{B}'_{1,0,1,0} + \mathrm{B}'_{1,0,0,1} \\ &+ \mathrm{B}'_{0,2,0,0} + \mathrm{B}'_{0,1,1,0} + \mathrm{B}'_{0,1,0,1} \\ &+ \mathrm{B}'_{0,0,2,0} + \mathrm{B}'_{0,0,1,1} + \mathrm{B}'_{0,0,0,2}; \end{aligned}\right\} \quad \ldots \quad (155.)$$

$$\left.\begin{aligned} \mathrm{C}' = \mathrm{C}'_{3,0,0,0} &+ \mathrm{C}'_{2,1,0,0} + \mathrm{C}'_{2,0,1,0} + \mathrm{C}'_{2,0,0,1} \\ &+ \mathrm{C}'_{1,2,0,0} + \mathrm{C}'_{1,1,1,0} + \mathrm{C}'_{1,1,0,1} \\ &+ \mathrm{C}'_{1,0,2,0} + \mathrm{C}'_{1,0,1,1} + \mathrm{C}'_{1,0,0,2} \\ &+ \mathrm{C}'_{0,3,0,0} + \mathrm{C}'_{0,2,1,0} + \mathrm{C}'_{0,2,0,1} \\ &+ \mathrm{C}'_{0,1,2,0} + \mathrm{C}'_{0,1,1,1} + \mathrm{C}'_{0,1,0,2} \\ &+ \mathrm{C}'_{0,0,3,0} + \mathrm{C}'_{0,0,2,1} + \mathrm{C}_{0,0,1,2} + \mathrm{C}'_{0,0,0,3}; \end{aligned}\right\} \quad \ldots \quad (156.)$$

each part $\mathrm{A}'_{h,i,k,l}$ or $\mathrm{B}'_{h,i,k,l}$ or $\mathrm{C}'_{h,i,k,l}$ being itself a rational and integral function of the twenty-one quantities (150) (151) (152) (153), and being also homogeneous of the degree h with respect to the three quantities (150), of the degree i with respect to the four quantities (151), of the degree k with respect to the six quantities (152), and of the degree l with respect to the eight quantities (153). He would then determine the two ratios of the two first to the last of the three quantities (150) (that is, the ratios of Λ' and Λ'' to Λ''') so as to satisfy the two conditions

$$\mathrm{A}'_{1,0,0,0} = 0, \ \mathrm{B}'_{2,0,0,0} = 0; \quad \ldots \quad (157.)$$

the three ratios of the first three to the last of the four quantities (151), so as to satisfy the three conditions

$$\mathrm{A}'_{0,1,0,0} = 0, \ \mathrm{B}'_{1,1,0,0} = 0, \ \mathrm{B}'_{0,2,0,0} = 0; \quad \ldots \quad (158.)$$

the ratio of the last of the quantities (150) to the last of the quantities (151), so as to satisfy the condition

$$\mathrm{C}'_{3,0,0,0} + \mathrm{C}'_{2,1,0,0} + \mathrm{C}'_{1,2,0,0} + \mathrm{C}'_{0,3,0,0} = 0; \quad \ldots \quad (159.)$$

the five ratios of the five first to the last of the six quantities (152), so as to satisfy the five conditions

$$\left.\begin{array}{l} A'_{0,0,1,0} = 0, \\ B'_{1,0,1,0} + B'_{0,1,1,0} = 0, \\ B'_{0,0,2,0} = 0, \\ C'_{2,0,1,0} + C'_{1,1,1,0} + C'_{0,2,1,0} = 0, \\ C'_{1,0,2,0} + C'_{0,1,2,0} = 0\,; \end{array}\right\} \quad . \quad . \quad . \quad . \quad (160.)$$

the seven ratios of the seven first to the last of the eight quantities (153), so as to satisfy the seven conditions

$$\left.\begin{array}{l} A'_{0,0,0,1} = 0, \\ B'_{1,0,0,1} + B'_{0,1,0,1} = 0, \\ B'_{0,0,1,1} = 0, \qquad B'_{0,0,0,2} = 0, \\ C'_{2,0,0,1} + C'_{1,1,0,1} + C'_{0,2,0,1} = 0, \\ C'_{1,0,1,1} + C'_{0,1,1,1} = 0, \\ C'_{1,0,0,2} + C'_{0,1,0,2} = 0\,; \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad (161.)$$

and the ratio of the last of the quantities (152) to the last of the quantities (153), so as to satisfy the condition

$$C'_{0,0,3,0} + C'_{0,0,2,1} + C'_{0,0,1,2} + C'_{0,0,0,3} = 0 : \quad . \quad . \quad . \quad (162.)$$

all which determinations could in general be successively effected, without its being necessary to resolve any equation of a higher degree than the fourth. The first part of the process would be now completed; that is, the assumed expression (149) for y would be reduced to the form

$$y = f(x) = \mathrm{M}^{\mathrm{IV}}\, \phi(x) + \Xi^{\mathrm{VIII}}\, \chi(x), \quad . \quad . \quad . \quad . \quad (163.)$$

the functions $\phi(x)$ and $\chi(x)$ being determined and known, but the multipliers M^{IV} and Ξ^{VIII} being arbitrary, and this expression (163) being such as to satisfy the three conditions (8) (10) and (14),

$$A' = 0, \quad B' = 0, \quad C' = 0\,;$$

nineteen out of the twenty ratios of the twenty-one coefficients (150) (151) (152) (153) having been determined so as to satisfy the nineteen equations (157) (158) (159) (160) (161) (162), into which those three conditions had been decomposed. And the second and only remaining part of the process would consist in then determining the remaining ratio of M^{IV} to Ξ^{VIII}, so as to satisfy the remaining condition

$$D' = 0, \quad . \quad . \quad . \quad (17.)$$

and thereby to reduce the general equation of the m^{th} degree,

$$\left.\begin{aligned} X = x^m + A\,x^{m-1} + B\,x^{m-2} + C\,x^{m-3} + D\,x^{m-4} \\ + E\,x^{m-5} + \&c. = 0, \end{aligned}\right\} \quad (1.)$$

to the form

$$Y = y^m + E'\,y^{m-5} + \&c. = 0. \quad . \quad . \quad (15.)$$

It is possible, of course, that this may not be precisely the same as Mr. Jerrard's unpublished process, but it seems likely that the one would not be found to differ from the other in any essential respect, notation being always excepted. It is, at least, a process suggested by the published researches of that author, and harmonizing with the discoveries which they contain.

But by applying to this new process the spirit of the former discussions, and putting, for abbreviation,

$$\left.\begin{aligned} &\Lambda'\,s_0^{(\lambda')} + \Lambda''\,s_0^{(\lambda'')} + \Lambda'''\,s_0^{(\lambda''')} + \mathrm{M}'\,s_0^{(\mu')} + \ldots \\ &\qquad + \mathrm{M}^{\mathrm{IV}}\,s_0^{(\mu^{\mathrm{IV}})} = p_0, \\ &\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ &\Lambda'\,s_{m-1}^{(\lambda')} + \Lambda''\,s_{m-1}^{(\lambda'')} + \Lambda'''\,s_{m-1}^{(\lambda''')} + \mathrm{M}'\,s_{m-1}^{(\mu')} + \ldots \\ &\qquad + \mathrm{M}^{\mathrm{IV}}\,s_{m-1}^{(\mu^{\mathrm{IV}})} = p_{m-1}, \end{aligned}\right\} \ldots (164.)$$

$$\left.\begin{aligned} &\mathrm{N}'\,s_0^{(\nu')} + \ldots + \mathrm{N}^{\mathrm{VI}}\,s_0^{(\nu^{\mathrm{VI}})} = p'_0, \\ &\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ &\mathrm{N}'\,s_{m-1}^{(\nu')} + \ldots + \mathrm{N}^{\mathrm{VI}}\,s_{m-1}^{(\nu^{\mathrm{VI}})} = p'_{m-1}, \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (165.)$$

$$\left.\begin{aligned} &\Xi'\,s_0^{(\xi')} + \ldots + \Xi^{\mathrm{VIII}}\,s_0^{(\xi^{\mathrm{VIII}})} = p''_0, \\ &\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ &\Xi'\,s_{m-1}^{(\xi')} + \ldots + \Xi^{\mathrm{VIII}}\,s_{m-1}^{(\xi^{\mathrm{VIII}})} = p''_{m-1}, \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (166.)$$

$$\left.\begin{aligned} &\Lambda'\,\mathrm{L}^{(\lambda')} + \Lambda''\,\mathrm{L}^{(\lambda'')} + \Lambda'''\,\mathrm{L}^{(\lambda''')} + \mathrm{M}'\,\mathrm{L}^{(\mu')} + \ldots \\ &\qquad + \mathrm{M}^{\mathrm{IV}}\,\mathrm{L}^{(\mu^{\mathrm{IV}})} \\ &\quad + \mathrm{N}'\,\mathrm{L}^{(\nu')} + \ldots + \mathrm{N}^{\mathrm{VI}}\,\mathrm{L}^{(\nu^{\mathrm{VI}})} + \Xi'\,\mathrm{L}^{(\xi')} + \ldots \\ &\qquad + \Xi^{\mathrm{VIII}}\,\mathrm{L}^{(\xi^{\mathrm{VIII}})} = \mathrm{L}, \end{aligned}\right\} \quad (167.)$$

we may change the expression (149) to the form (100), through the theorem and notation (44); and in order to avoid the case of failure, in which the functions $\phi\,(x)$ and $\chi\,(x)$ in (163) are

connected by a relation of the form (36), we must avoid, as in the discussion given in the seventh article, the case where the m sums $p'_0 + p''_0, \dots p'_{m-1} + p''_{m-1}$ are proportional to the m quantities $p_0, \dots p_{m-1}$, that is, the case

$$q_0 + q'_0 = 0, \dots q_{m-2} + q'_{m-2} = 0, \quad . \quad . \quad . \quad (102.)$$

if we adopt the definitions (54) (55) and (96) (97), so as to introduce the symbols $p, q_0, q_1, \dots q_{m-2}$, and $p', q'_0, q'_1, \dots q'_{m-2}$. With these additional symbols it is easy to transform the conditions (160) into others, which (when suitably combined with the equations of definition, and with the ratios of $p_0, \dots p_{m-1}$ already previously determined through the help of the conditions (157) (158) (159),) shall serve to determine the ratios (121) of $q_0, \dots q_{m-2}$; and then to determine, in like manner, with the help of the conditions (161), the ratios (120) of $q'_0, \dots q'_{m-2}$; after which, the condition (162) may be transformed into a rational and integral and homogeneous equation of the third degree between the sums $q_0 + q'_0, \dots q_{m-2} + q'_{m-2}$, and will in general oblige those sums to vanish, if their ratios (122) have been already determined independently of this condition (162), which will happen when the ratios (120) coincide with the ratios (121), that is, when the quantities $q'_0, \dots q'_{m-1}$ are proportional to the quantities $q_0, \dots q_{m-1}$. We must, therefore, in general avoid this last proportionality, in order to avoid the case of failure (102); and thus we are led to introduce the symbols $q, r_0, r_1, \dots r_{m-3}$, defined by the equations (124) (125), and to express the case of failure by the equations

$$r_0 = 0, \ r_1 = 0, \dots r_{m-3} = 0. \quad . \quad . \quad . \quad (126.)$$

With these new symbols we easily discover that the seven conditions (161) may be reduced to seven rational and integral and homogeneous equations between the quantities $r_0, r_1, \dots r_{m-3}$, which will in general oblige them all to vanish, and therefore will produce the case of failure (126), *unless the number* $m - 2$ *of these quantities be greater than the number seven,* that is, *unless the exponent m of the degree of the proposed equation be at least equal to the minor limit* TEN. It results, then, from this discussion, that the process described in the present article *will not in general avail to take away four terms at once, from equations lower than the* TENTH *degree,* and, of course, that *it will not reduce the general equation of the fifth degree,*

$$x^5 + \mathrm{A}\,x^4 + \mathrm{B}\,x^3 + \mathrm{C}\,x^2 + \mathrm{D}\,x + \mathrm{E} = 0, \quad . \quad . \quad (69.)$$

to the binomial form

$$y^5 + \mathrm{E}' = 0, \quad \ldots \ldots \quad (168.)$$

except by the useless assumption

$$y = \mathrm{L}\,(x^5 + \mathrm{A}\,x^4 + \mathrm{B}\,x^3 + \mathrm{C}\,x^2 + \mathrm{D}\,x + \mathrm{E}), \;.\;. \; (138.)$$

which gives

$$y^5 = 0. \quad \ldots \quad (139.)$$

[11.] A principal feature of Mr. Jerrard's general method is to *avoid*, as much as possible, *the raising of degree in elimination*; and for that purpose to *decompose the equations of condition* in every question *into groups*, which shall *each* contain, if possible, *not more than one equation of a higher degree than the first*; although the occurrence of *two equations of the second degree* in one group is *not fatal* to the success of the method, because the final equation of such a group being *only elevated to the fourth degree*, can be resolved by the known rules. It might, therefore, have been more completely in the spirit of this general method, because it would have more completely avoided the elevation of degree by elimination, if, in order to take away four terms at once from the general equation of the mth degree, we had assumed an expression with *thirty-three* terms, of the form

$$\left.\begin{aligned} y = f(x) = {} & \Lambda' x^{\lambda'} + \Lambda'' x^{\lambda''} + \Lambda''' x^{\lambda'''} \\ & + \mathrm{M}' x^{\mu'} + \ldots + \mathrm{M}^{\mathrm{IV}} x^{\mu^{\mathrm{IV}}} \\ & + \mathrm{N}' x^{\nu'} + \ldots + \mathrm{N}^{\mathrm{V}} x^{\nu^{\mathrm{V}}} \\ & + \Xi' x^{\xi'} + \ldots + \Xi^{\mathrm{VI}} x^{\xi^{\mathrm{VI}}} \\ & + \mathrm{O}' x^{o'} + \ldots + \mathrm{O}^{\mathrm{VII}} x^{o^{\mathrm{VII}}} \\ & + \Pi' x^{\varpi'} + \ldots + \Pi^{\mathrm{VIII}} x^{\varpi^{\mathrm{VIII}}}; \end{aligned}\right\} \ldots \; (169.)$$

and had determined the six ratios of $\Lambda', \Lambda'', \Lambda''', \mathrm{M}', \ldots \mathrm{M}^{\mathrm{IV}}$, and the twenty-five ratios of $\mathrm{N}', \ldots \Pi^{\mathrm{VIII}}$, so as to satisfy the thirty-one conditions

$$\mathrm{A}'_{1,0,0,0,0,0} = 0,\ \mathrm{B}'_{2,0,0,0,0,0} = 0, \quad \ldots \ldots \quad (170.)$$

$$\mathrm{A}'_{0,1,0,0,0,0} = 0,\ \mathrm{B}'_{1,1,0,0,0,0} = 0,\ \mathrm{B}'_{0,2,0,0,0,0} = 0, \quad \ldots \quad (171.)$$

$$\mathrm{C}'_{3,0,0,0,0,0} + \mathrm{C}'_{2,1,0,0,0,0} + \mathrm{C}'_{1,2,0,0,0,0} + \mathrm{C}'_{0,3,0,0,0,0} = 0, \quad (172.)$$

$$\left.\begin{aligned} & \mathrm{A}'_{0,0,1,0,0,0} = 0, \\ & \mathrm{B}'_{1,0,1,0,0,0} + \mathrm{B}'_{0,1,1,0,0,0} = 0, \\ & \mathrm{B}'_{0,0,2,0,0,0} = 0, \\ & \mathrm{C}'_{2,0,1,0,0,0} + \mathrm{C}'_{1,1,1,0,0,0} + \mathrm{C}'_{0,2,1,0,0,0} = 0, \end{aligned}\right\} \ldots \; (173.)$$

$$\left.\begin{aligned}
&A'_{0,0,0,1,0,0} = 0,\\
&B'_{1,0,0,1,0,0} + B'_{0,1,0,1,0,0} = 0,\\
&B'_{0,0,1,1,0,0} = 0,\\
&B'_{0,0,0,2,0,0} = 0,\\
&C'_{2,0,0,1,0,0} + C'_{1,1,0,1,0,0} + C'_{0,2,0,1,0,0} = 0,
\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (174.)$$

$$\left.\begin{aligned}
&C'_{1,0,2,0,0,0} + C'_{1,0,1,1,0,0} + C'_{1,0,0,2,0,0}\\
&+ C'_{0,1,2,0,0,0} + C'_{0,1,1,1,0,0} + C'_{0,1,0,2,0,0} = 0,
\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (175.)$$

$$\left.\begin{aligned}
&A'_{0,0,0,0,1,0} = 0,\\
&B'_{1,0,0,0,1,0} + B'_{0,1,0,0,1,0} = 0,\\
&B'_{0,0,1,0,1,0} + B'_{0,0,0,1,1,0} = 0,\\
&B'_{0,0,0,0,2,0} = 0,\\
&C'_{2,0,0,0,1,0} + C'_{1,1,0,0,1,0} + C'_{0,2,0,0,1,0} = 0,\\
&C'_{1,0,1,0,1,0} + C'_{1,0,0,1,1,0} + C'_{0,1,1,0,1,0} + C'_{0,1,0,1,1,0} = 0,
\end{aligned}\right\} (176.)$$

$$\left.\begin{aligned}
&A'_{0,0,0,0,0,1} = 0,\\
&B'_{1,0,0,0,0,1} + B'_{0,1,0,0,0,1} = 0,\\
&B'_{0,0,1,0,0,1} + B'_{0,0,0,1,0,1} = 0,\\
&B'_{0,0,0,0,1,1} = 0,\\
&B'_{0,0,0,0,0,2} = 0,\\
&C'_{2,0,0,0,0,1} + C'_{1,1,0,0,0,1} + C'_{0,2,0,0,0,1} = 0,\\
&C'_{1,0,1,0,0,1} + C'_{1,0,0,1,0,1} + C'_{0,1,1,0,0,1} + C'_{0,1,0,1,0,1} = 0,
\end{aligned}\right\} (177.)$$

$$\left.\begin{aligned}
&C'_{1,0,0,0,2,0} + C'_{1,0,0,0,1,1} + C'_{1,0,0,0,0,2}\\
&+ C'_{0,1,0,0,2,0} + C'_{0,1,0,0,1,1} + C'_{0,1,0,0,0,2} = 0,
\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (178.)$$

$$\left.\begin{aligned}
&C'_{0,0,3,0,0,0} + C'_{0,0,2,1,0,0} + C'_{0,0,2,0,1,0} + C'_{0,0,2,0,0,1}\\
&+ C'_{0,0,1,2,0,0} + C'_{0,0,1,1,1,0} + C'_{0,0,1,1,0,1}\\
&+ C'_{0,0,1,0,2,0} + C'_{0,0,1,0,1,1} + C'_{0,0,1,0,0,2}\\
&+ C'_{0,0,0,3,0,0} + C'_{0,0,0,2,1,0} + C'_{0,0,0,2,0,1}\\
&+ C'_{0,0,0,1,2,0} + C'_{0,0,0,1,1,1} + C'_{0,0,0,1,0,2}\\
&+ C'_{0,0,0,0,3,0} + C'_{0,0,0,0,2,1} + C'_{0,0,0,0,1,2} + C'_{0,0,0,0,0,3} = 0,
\end{aligned}\right\} (179.)$$

into which the three conditions

$$A' = 0,\ B' = 0,\ C' = 0,$$

may be decomposed; the symbol $A'_{f,g,h,i,k,l}$ or $B'_{f,g,h,i,k,l}$ or $C'_{f,g,h,i,k,l}$ denoting here a rational and integral function of the thirty-three coefficients $\Lambda', \ldots \Pi^{\mathrm{VIII}}$, which is homogeneous of the degree f with respect to $\Lambda', \Lambda'', \Lambda'''$, of the degree g with respect to $M', \ldots M^{\mathrm{IV}}$, of the degree h with respect to $N', \ldots N^{\mathrm{V}}$, of the degree i with respect to $\Xi', \ldots \Xi^{\mathrm{VI}}$, of the degree k with respect to $O', \ldots O^{\mathrm{VII}}$, and of the degree l with respect to $\Pi', \ldots \Pi^{\mathrm{VIII}}$: while the remaining ratio of M^{IV} to Π^{VIII}, should afterwards be chosen so as to satisfy the remaining condition

$$D' = 0.$$

But, upon putting, for abridgement,

$$\left.\begin{array}{l} N' s_0^{(\nu')} + \ldots + N^{\mathrm{V}} s_0^{(\nu^{\mathrm{V}})} + \Xi' s_0^{(\xi')} + \ldots \\ \qquad + \Xi^{\mathrm{VI}} s_0^{(\xi^{\mathrm{VI}})} = p'_0, \\ \cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot \\ N' s^{(\nu')}_{m-1} + \ldots + N^{\mathrm{V}} s^{(\nu^{\mathrm{V}})}_{m-1} + \Xi' s^{(\xi')}_{m-1} + \ldots \\ \qquad + \Xi^{\mathrm{VI}} s^{(\xi^{\mathrm{VI}})}_{m-1} = p'_{m-1}, \end{array}\right\} \quad . \quad . \quad (180.)$$

$$\left.\begin{array}{l} O' s_0^{(o')} + \ldots + O^{\mathrm{VII}} s_0^{(o^{\mathrm{VII}})} = p''_0, \\ \cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot \\ O' s^{(o')}_{m-1} + \ldots + O^{\mathrm{VII}} s^{(o^{\mathrm{VII}})}_{m-1} = p''_{m-1}, \end{array}\right\} \quad . \quad . \quad (181.)$$

$$\left.\begin{array}{l} \Pi' s_0^{(\varpi')} + \ldots + \Pi^{\mathrm{VIII}} s_0^{(\varpi^{\mathrm{VIII}})} = p_0''', \\ \cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot \\ \Pi' s^{(\varpi')}_{m-1} + \ldots + \Pi^{\mathrm{VIII}} s^{(\varpi^{\mathrm{VIII}})}_{m-1} = p'''_{m-1}, \end{array}\right\} \quad . \quad . \quad . \quad (182.)$$

$$\left.\begin{array}{l} \Lambda' L^{(\lambda')} + \Lambda'' L^{(\lambda'')} + \Lambda''' L^{(\lambda''')} + M' L^{(\mu')} + \ldots \\ \qquad + M^{\mathrm{IV}} L^{(\mu^{\mathrm{IV}})} \\ + N' L^{(\nu')} + \ldots + N^{\mathrm{V}} L^{(\nu^{\mathrm{V}})} + \Xi' L^{(\xi')} + \ldots \\ \qquad + \Xi^{\mathrm{VI}} L^{(\xi^{\mathrm{VI}})} \\ + O' L^{(o')} + \ldots + O^{\mathrm{VII}} L^{(o^{\mathrm{VII}})} + \Pi' L^{(\varpi')} + \ldots \\ \qquad + \Pi^{\mathrm{VIII}} L^{(\varpi^{\mathrm{VIII}})} = L, \end{array}\right\} \quad (183.)$$

$$\frac{p'''_{m-1}}{p_{m-1}} = p'', \quad \ldots \ldots \quad (184.)$$

$$p_0''' - p''p_0 = q_0'', \ldots p'''_{m-2} - p''p_{m-2} = q''_{m-2}, \quad (185.)$$

$$\frac{q''_{m-2}}{q_{m-2}} = q', \quad \ldots \ldots \quad (186.)$$

$$q_0'' - q'q_0 = r_0', \ldots q''_{m-3} - q'q_{m-3} = r'_{m-3}, \quad \ldots \quad (187.)$$

$$\frac{r'_{m-3}}{r_{m-3}} = r, \quad \ldots \ldots \quad (188.)$$

$$r_0' - r\,r_0 = t_0, \ldots r'_{m-4} - r\,r_{m-4} = t_{m-4}, \quad \ldots \quad (189.)$$

and retaining the analogous expressions (164.) (54.) (55.) (96.) (97.) (124.) (125.), we find, by a reasoning exactly analogous to that employed in the former discussions, that the final expression for y will in general be of the useless form

$$y = \mathrm{L\,X}, \quad \ldots \ldots \quad (190.)$$

in the following case of failure,

$$t_0 = 0, t_1 = 0, \ldots t_{m-4} = 0; \quad \ldots \ldots \quad (191.)$$

and on the other hand that the seven conditions (177.) may be reduced to the form of seven rational and integral and homogeneous equations between these $m - 3$ quantities $t_0, t, \ldots t_{m-4}$; so that the case of failure will in general occur in the employment of the *present* process, *unless the number* $m - 3$ *be greater than seven*, that is, *unless the degree* m *of the proposed equation in* x *be at least equal to the minor limit eleven.*

It must, however, be remembered that the less complex process described in the foregoing article, (since it contained no condition, nor group of conditions, in which the dimension, or the product of the dimensions, exceeded the number four,) agreed sufficiently with the spirit of Mr. Jerrard's general method; and was adequate to take away four terms at once from the general equation of the *tenth*, or of any higher degree.

[12.] The various processes described in the 2nd, 5th, 6th and 11th articles of this communication, for *transforming the general equation of the mth degree*, by satisfying certain systems of equations of condition, are connected with the solution of this far more general problem proposed by Mr. Jerrard, "to discover $m - 1$ ratios of m disposable quantities,

$$a_1, a_2, \ldots a_m, \quad \ldots \ldots \quad (192.)$$

which shall satisfy a given system of h_1 rational and integral and homogeneous equations of the first degree,

$$A' = 0,\ A'' = 0, \ldots A^{(h_1)} = 0; \quad \ldots \quad (193.)$$

h_2 such equations of the second degree,

$$B' = 0,\ B'' = 0, \ldots B^{(h_2)} = 0; \quad \ldots \quad (194.)$$

h_3 of the third degree,

$$C' = 0,\ C'' = 0, \ldots C^{(h_3)} = 0; \quad \ldots \quad (195.)$$

and so on, as far as h_t equations of the tth degree,

$$T' = 0,\ T'' = 0, \ldots T^{(h_t)} = 0, \quad \ldots \quad (196.)$$

without being obliged in any part of the process, to introduce any elevation of degree by elimination." Mr. Jerrard has not published his solution of this very general problem, but he has sufficiently suggested the method which he would employ, and it is proper to discuss it briefly here, with reference to the extent of its application, and the circumstances under which it fails; not only on account of the importance of such discussion in itself, but also because it is adapted to throw light on all the questions already considered.

If we asume

$$a_1 = a'_1 + a''_1,\ a_2 = a'_2 + a''_2, \ldots a_m = a'_m + a''_m, \quad \ldots \quad (197.)$$

that is, if we decompose each of the m disposable quantities $a_1, a_2, \ldots a_m$ into two parts, we may then accordingly decompose every one of the h_1 proposed homogeneous functions of those m quantities, which are of the first degree, namely,

$$A', A'', \ldots A^{(\alpha)}, \ldots A^{(h_1)}; \quad \ldots \quad (198.)$$

every one of the h_2 proposed functions of the second degree,

$$B', B'', \ldots B^{(\beta)}, \ldots B^{(h_2)}; \quad \ldots \quad (199.)$$

every one of the h_3 functions of the third degree,

$$C', C'', \ldots C^{(\gamma)}, \ldots C^{(h_3)}; \quad \ldots \quad (200.)$$

and so on, as far as all the first $h_t - 1$ functions of the tth degree,

$$T', T'', \ldots T^{(\tau)}, \ldots T^{(h_t - 1)}, \quad \ldots \quad (201.)$$

(the last function $T^{(h_t)}$ being reserved for another purpose, which

will be presently explained,) into other homogeneous functions, according to the general types,

$$\left.\begin{array}{l} A^{(\alpha)} = A^{(\alpha)}{}_{1,0} + A^{(\alpha)}{}_{0,1}; \\ B^{(\beta)} = B^{(\beta)}{}_{2,0} + B^{(\beta)}{}_{1,1} + B^{(\beta)}{}_{0,2}, \\ C^{(\gamma)} = C^{(\gamma)}{}_{3,0} + C^{(\gamma)}{}_{2,1} + C^{(\gamma)}{}_{1,2} + C^{(\gamma)}{}_{0,3}, \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ T^{(\tau)} = T^{(\tau)}_{t,0} + T^{(\tau)}_{t-1,1} + \ldots + T^{(\tau)}_{0,t}: \end{array}\right\} \quad . \quad (202.)$$

each symbol of the class

$$A^{(\alpha)}_{p,q},\ B^{(\beta)}_{p,q},\ C^{(\gamma)}_{p,q}, \ldots T^{(\tau)}_{p,q}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (203.)$$

denoting a rational and integral and homogeneous function of the $2\,m$ new quantities,

$$a'_1, a'_2, \ldots a'_m, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (204.)$$

and

$$a''_1, a''_2, \ldots a''_m, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (205.)$$

which function is homogeneous of the degree p with respect to the quantities (204), and of the degree q with respect to the quantities (205). By this decomposition, we may substitute, instead of the problem first proposed, the system of the three following auxiliary problems. First, to satisfy, by ratios of the m quantities (204), an auxiliary system of equations, containing h_1 equations of the first degree, namely,

$$A'_{1,0} = 0,\ A''_{1,0} = 0, \ldots A^{(h_1)}{}_{1,0} = 0; \quad . \quad . \quad . \quad . \quad . \quad . \quad (206.)$$

h_2 equations of the second degree,

$$B'_{2,0} = 0,\ B''_{2,0} = 0, \ldots B^{(h_2)}{}_{2,0} = 0; \quad . \quad . \quad . \quad . \quad (207.)$$

h_3 of the third degree,

$$C'_{3,0} = 0,\ C''_{3,0} = 0, \ldots C^{(h_3)}{}_{3,0} = 0; \quad . \quad . \quad . \quad . \quad . \quad (208.)$$

and so on, as far as the following $h_t - 1$ equations of the tth degree,

$$T'_{t,0} = 0,\ T''_{t,0} = 0, \ldots T^{(h_t - 1)}_{t,0} = 0. \quad . \quad . \quad . \quad . \quad . \quad (209.)$$

Second, to satisfy, by ratios of the m quantities (205.), a system containing $h_1 + h_2 + h_3 + \ldots + h_t - 1$ equations, which are of the first degree with respect to those m quantities, and are of the forms

$$\mathrm{A}^{(\alpha)}_{0,1} = 0,\ \mathrm{B}^{(\beta)}_{1,1} = 0,\ \mathrm{C}^{(\gamma)}_{2,1} = 0, \ldots \mathrm{T}^{(\tau)}_{t-1,1} = 0; \quad \ldots \quad (210.)$$

$h_2 + h_3 + \ldots + h_t - 1$ equations of the second degree, and of the forms

$$\mathrm{B}^{(\beta)}_{0,2} = 0,\ \mathrm{C}^{(\gamma)}_{1,2} = 0, \ldots \mathrm{T}^{(\tau)}_{t-2,2} = 0; \quad \ldots \quad (211.)$$

$h_3 + \ldots + h_t - 1$ equations of the third degree, and of the forms

$$\mathrm{C}^{(\gamma)}_{0,3} = 0, \ldots \mathrm{T}^{(\tau)}_{t-3,3} = 0; \quad \ldots \quad (212.)$$

and so on, as far as $h_t - 1$ equations of the tth degree, namely,

$$\mathrm{T}'_{0,t} = 0,\ \mathrm{T}''_{0,t} = 0, \ldots \mathrm{T}^{(h_t - 1)}_{0,t} = 0. \quad \ldots \quad (213.)$$

And third, to satisfy, by the ratio of any one of the m quantities (205.) to any one of the m quantities (204.), this one remaining equation of the tth degree,

$$\mathrm{T}^{(h_t)} = 0. \quad \ldots \quad (214.)$$

For if we can resolve all these three auxiliary problems, we shall thereby have resolved the original problem also. And there is this advantage in thus transforming the question, that whereas there were h_t equations of the highest (that is of the tth) degree, in the problem originally proposed, there are only $h_t - 1$ equations of that highest degree, in each of the two first auxiliary problems, and only one such equation in the third. If, then, we apply the same process of transformation to each of the two first auxiliary problems, and repeat it sufficiently often, we shall get rid of all the equations of the tth degree, and ultimately of all equations of degrees higher than the first; with the exception of certain equations, which are at various stages of the process set aside to be separately and singly resolved, without any such combination with others as could introduce an elevation of degree by elimination. And thus, at last, the original problem may doubtless be resolved, *provided that the number m, of quantities originally disposable, be large enough.*

[13.] But that some such condition respecting the magnitude of that number m is necessary, will easily appear, if we observe that when m is not large enough to satisfy the inequality,

$$m > h_1 + h_2 + h_3 + \ldots + h_t, \quad \ldots \quad (215.)$$

then the original $h_1 + h_2 + h_3 + \ldots + h_t$ equations, being rational and integral and homogeneous with respect to the original

m quantities (192.), will in general conduct to null values for all those quantities, that is, to the expressions

$$a_1 = 0, a_2 = 0, \ldots a_m = 0, \quad \ldots \ldots \quad (216.)$$

and therefore to a result which we designed to exclude; because by the enunciation of the original problem it was by the $m - 1$ *ratios* of those m quantities that we were to satisfy, if possible, the equations originally proposed. The same excluded case, or case of failure (216.), will in general occur when the solution of the second auxiliary problem gives ratios for the m auxiliary quantities (205.), which coincide with the ratios already found in resolving the first auxiliary problem for the m other auxiliary quantities (204.); that is, when the two first problems conduct to expressions of the forms

$$a''_1 = a\,a'_1, a''_2 = a\,a'_2, \ldots a''_m = a\,a'_m, \quad \ldots \quad (217.)$$

a being any common multiplier; for then these two first problems conduct, in virtue of the definitions (197.), to a determined set of ratios for the m original quantities (192.), namely,

$$\frac{a_1}{a_m} = \frac{a'_1}{a'_m}, \ldots \frac{a_{m-1}}{a_m} = \frac{a'_{m-1}}{a'_m}; \quad \ldots \ldots \quad (218.)$$

and unless these ratios happen to satisfy the equation of the third problem (214), which had not been employed in determining them, that last homogeneous equation (214.) will oblige all those m quantities (192.) to vanish, and so will conduct to the case of failure (216). Now although, when the condition (215) is satisfied, the first auxiliary problem becomes indeterminate, because

$$m - 1 > h_1 + h_2 + h_3 + \ldots + h_t - 1,$$

so that the number $m - 1$ of the disposable ratios of the m auxiliary quantities (204) is greater than the number of the homogeneous equations which those m quantities are to satisfy, yet whatever system of $m - 1$ such ratios

$$\frac{a'_1}{a'_m}, \frac{a'_2}{a'_m}, \ldots \frac{a'_{m-1}}{a'_m}, \quad \ldots \ldots \ldots \quad (219.)$$

we may discover and employ, so as to satisfy the equations of the first auxiliary problem, it will always be possible to satisfy the equations of the second auxiliary problem also, by employing the same system of $m - 1$ ratios for the m other auxiliary quantities (205), that is, by employing expressions for those quantities of the forms (217); and, reciprocally, it will in general be impossible to resolve the second auxiliary problem

otherwise, unless the number of its equations be less than $m-1$. For if we put, for abridgement,

$$\frac{a''_m}{a'_m} = a, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (220.)$$

and

$$a''_1 - a\,a'_1 = b_1, a''_2 - a\,a'_2 = b_2, \ldots a''_{m-1} - a\,a'_{m-1} = b_{m-1}, \quad (221.)$$

we shall have, as a general system of expressions for the m quantities (205.), the following,

$$\left.\begin{array}{l} a''_1 = a\,a'_1 + b_1,\ a''_2 = a\,a'_2 + b_2, \ldots a''_{m-1} = a\,a'_{m-1} \\ \qquad + b_{m-1},\ a''_m = a\,a'_m; \end{array}\right\} \quad (222.)$$

and therefore by (197),

$$\left.\begin{array}{l} a_1 = (1 + a)\,a'_1 + b_1, \ldots a_{m-1} = (1 + a)\,a'_{m-1} \\ \qquad + b_{m-1},\ a_m = (1 + a)\,a'_m; \end{array}\right\} \quad . \quad . \quad . \quad (223.)$$

so that the homogeneous functions $A^{(\alpha)}$, $B^{(\beta)}$, $\ldots T^{(\tau)}$ may be, in general, decomposed in this new way,

$$\left.\begin{array}{l} A^{(\alpha)} = (1 + a)\,A'^{(\alpha)}_{1,0} + A'^{(\alpha)}_{0,1}; \\ B^{(\beta)} = (1 + a)^2\,B'^{(\beta)}_{2,0} + (1 + a)\,B'^{(\beta)}_{1,1} + B'^{(\beta)}_{0,2}; \\ . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \\ T^{(\tau)} = (1 + a)^t\,T'^{(\tau)}_{t,0} + (1 + a)^{t-1}\,T'^{(\tau)}_{t-1,0} + \ldots \\ \qquad + T'^{(\tau)}_{0,t}: \end{array}\right\} . \quad (224.)$$

each symbol of the class

$$A'^{(\alpha)}_{p,q},\ B'^{(\beta)}_{p,q}, \ldots T'^{(\tau)}_{p,q} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (225.)$$

denoting a rational and integral function of the $2m - 1$ quantities $a'_1, \ldots a'_m, b_1, \ldots b_{m-1}$, which is homogeneous of the dimension p with respect to the m quantities

$$a'_1, \ldots a'_m, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (204)$$

and of the dimension q with respect to the $m - 1$ quantities

$$b_1, \ldots b_{m-1}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (226.)$$

but is independent of the multiplier a. And the identical equations obtained by comparing the expressions (202) and (224), resolve themselves into the following:

$$\left.\begin{aligned}
&A^{(\alpha)}_{1,0} = A'^{(\alpha)}_{1,0};\ A^{(\alpha)}_{0,1} = a\,A'^{(\alpha)}_{1,0} + A'^{(\alpha)}_{0,1};\\
&B^{(\beta)}_{2,0} = B'^{(\beta)}_{2,0};\ B^{(\beta)}_{1,1} = 2\,a\,B'^{(\beta)}_{2,0} + B'^{(\beta)}_{1,1};\\
&\qquad B^{(\beta)}_{0,2} = a^2\,B'^{(\beta)}_{2,0} + a\,B'^{(\beta)}_{1,1} + B'^{(\beta)}_{0,2};\\
&\cdots\cdots\cdots\cdots\cdots\cdots\\
&T^{(\tau)}_{t,0} = T'^{(\tau)}_{t,0};\ T^{(\tau)}_{t-1,1} = t\,a\,T'^{(\tau)}_{t,0} + T'^{(\tau)}_{t-1,1};\\
&T^{(\tau)}_{t-2,2} = \frac{t\,(t-1)}{2}\,a^2\,T'^{(\tau)}_{t,0} + (t-1)\,a\,T'^{(\tau)}_{t-1,1}\\
&\qquad + T'^{(\tau)}_{t-2,2};\\
&\cdots\cdots\cdots\cdots\cdots\cdots\\
&T^{(\tau)}_{0,t} = a^t\,T'^{(\tau)}_{t,0} + a^{t-1}\,T'^{(\tau)}_{t-1,1} + \ldots + T'^{(\tau)}_{0,t};
\end{aligned}\right\} \quad . \quad (227.)$$

so that the first system of auxiliary equations, (206) ... (209), which are of the forms

$$A^{(\alpha)}_{1,0} = 0,\ B^{(\beta)}_{2,0} = 0,\ C^{(\gamma)}_{3,0} = 0, \ldots T^{(\tau)}_{t,0} = 0, \quad . \quad . \quad . \quad (228)$$

may be replaced by the system

$$A'^{(\alpha)}_{1,0} = 0,\ B'^{(\beta)}_{2,0} = 0,\ C'^{(\gamma)}_{3,0} = 0, \ldots T'^{(\tau)}_{t,0} = 0, \quad . \quad . \quad (229.)$$

the change, so far, being only a change of notation; and, after satisfying this system by a suitable selection of the ratios of the quantities (204), the second system of auxiliary equations, (210) ... (213), may then be transformed, with a real simplification, (which consists in getting rid of the arbitrary multiplier a, and in diminishing the number of the quantities whose ratios remain to be disposed of,) to another system of equations of the forms,

$$\left.\begin{aligned}
&A'^{(\alpha)}_{0,1} = 0,\ B'^{(\beta)}_{1,1} = 0,\ C'^{(\gamma)}_{2,1} = 0, \ldots T'^{(\tau)}_{t-1,1} = 0;\\
&B'^{(\beta)}_{0,2} = 0,\ C'^{(\gamma)}_{1,2} = 0, \ldots T'^{(\tau)}_{t-2,2} = 0;\\
&C'^{(\gamma)}_{0,3} = 0, \ldots T'^{(\tau)}_{t-3,3} = 0;\\
&\cdots\cdots\cdots\cdots\cdots\cdots\\
&T'^{(\tau)}_{0,t} = 0;
\end{aligned}\right\} \quad (230.)$$

which are rational and integral and homogeneous with respect to the $m-1$ quantities (226), and are independent of the multiplier a. Unless, then, the number of the equations of this transformed system (230), which is the same as the number of equations in the second auxiliary problem before proposed, be less than the number $m-1$ of the new auxiliary quantities (226), we shall have, in general, null values for all those quantities, that is, we shall have

$$b_1 = 0,\ b_2 = 0, \ldots b_{m-1} = 0; \quad \ldots \ldots \quad (231.)$$

and therefore we shall be conducted, by (222), to expressions of the forms (217), which will in general lead, as has been already shown, to the case of failure (216). We have therefore a *new condition of inequality*, which the number m must satisfy, in order to the general success of the method, namely the following,

$$m-1 > h'_1 + h'_2 + h'_3 + \ldots + h'_t; \quad \ldots \ldots \quad (232.)$$

in which, $h'_1, h'_2, h'_3, \ldots h'_t$ denote respectively the numbers of the equations of the first, second, third, ... and tth degrees, in the second auxiliary problem; so that, by what has been already shown,

$$\left.\begin{array}{l} h'_t = h_t - 1, \\ h'_{t-1} = h_{t-1} + h_t - 1, \\ h'_{t-2} = h_{t-2} + h_{t-1} + h_t - 1, \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ h'_2 = h_2 + \ldots + h_t - 1, \\ h'_1 = h_1 + h_2 \ldots + h_t - 1. \end{array}\right\} \quad \ldots \ldots \quad (233.)$$

These last expressions give

$$\left.\begin{array}{l} h'_1 + h'_2 + h'_3 + \ldots + h'_t = h_1 + 2\,h_2 + 3\,h_3 + \ldots \\ \qquad + t\,h_t - t; \end{array}\right\} (234.)$$

so that the new condition of inequality, (232), may be written as follows,

$$m-1 > h_1 + 2\,h_2 + 3\,h_3 + \ldots + t\,(h_t - 1); \quad \ldots \quad (235.)$$

and therefore also thus,

$$\left.\begin{array}{l} m > h_1 + h_2 + h_3 + \ldots + h_t \\ \qquad + h_2 + 2\,h_3 + \ldots + (t-1)(h_t - 1). \end{array}\right\} \quad \ldots \quad (236.)$$

It *includes*, therefore, in general, the old inequality (215); and may be considered as comprising in itself all the conditions respecting the magnitude of the number m, connected with our present inquiry: or, at least, as capable of furnishing us with all such conditions, if only it be sufficiently developed.

[14.] It must, however, be remembered, as a part of such development, that although, when this condition (232) or (235) or (236) is satisfied, the three auxiliary problems above stated are, in general, theoretically capable of being resolved, and of conducting to a system of ratios of the m original quantities (192), which shall satisfy the original system of equations, yet each of the two first auxiliary systems contains, in general, more than two equations of the second or higher degrees; and therefore that, in order to avoid any elevation of degree by elimination (as required by the original problem), the process must in general be *repeated*, and each of the two auxiliary systems themselves must be decomposed, and treated like the system originally proposed. These new decompositions introduce, in general, new conditions of inequality, analogous to the condition lately determined; but it is clear that the condition connected with the decomposition of the first of the auxiliary systems must be included in the condition connected with the decomposition of the second of those systems, because the latter system contains, in general, in each of the degrees $1, 2, 3, \ldots t-1$, a greater number of equations than the former, while both contain, in the degree t, the same number of equations, namely, $h_t - 1$. Conceiving, then, the second auxiliary system to be decomposed by a repetition of the process above described into two new auxiliary systems or groups of equations, and into one separate and reserved equation of the tth degree, we are conducted to this new condition of inequality, analogous to (232),

$$m - 2 > h''_1 + h''_2 + h''_3 + \ldots + h''_t; \quad . \quad . \quad . \quad . \quad (237.)$$

$h''_1, h''_2, h''_3, \ldots h''_t$ denoting, respectively, the numbers of equations of the first, second, third, ... and tth degrees, in the second new group of equations; in such a manner that, by the nature of the process,

$$\left.\begin{array}{l} h''_t = h'_t - 1, \\ h''_{t-1} = h'_{t-1} + h'_t - 1, \\ h''_{t-2} = h'_{t-2} + h'_{t-1} + h'_t - 1, \\ \quad . \quad . \quad . \\ h''_1 = h'_1 + h'_2 + \ldots + h'_t - 1. \end{array}\right\} \quad . \quad . \quad . \quad (238.)$$

Repeating this process, we find, next, the condition,

$$m - 3 > h'''_1 + h'''_2 + h'''_3 + \ldots + h'''_t; \quad . \quad . \quad . \quad (239.)$$

and generally

$$m - i > h^{(i)}_1 + h^{(i)}_2 + h^{(i)}_3 + \ldots + h^{(i)}_t; \quad . \quad . \quad . \quad (240.)$$

each new condition of this series including all that go before it, and the symbol $h^{(i)}_p$ being such that

$$h^{(o)}_p = h_p, \quad . \quad . \quad . \quad (241.)$$

$$h^{(i+1)}_t - h^{(i)}_t = -1, \quad . \quad . \quad . \quad (242.)$$

and

$$h^{(i+1)}_{t-n} - h^{(i)}_{t-n} = h^{(i+1)}_{t-n+1}. \quad . \quad . \quad . \quad (243.)$$

Integrating these last equations as equations in finite differences, we find

$$\left.\begin{array}{l}
h^{(i)}_t = h_t - i; \\
h^{(i)}_{t-1} = h_{t-1} + i\left(h_t - \frac{i+1}{2}\right); \\
h^{(i)}_{t-2} = h_{t-2} + i\,h_{t-1} + i \,.\, \frac{i+1}{2} \,.\, \left(h_t - \frac{i+2}{3}\right); \\
h^{(i)}_{t-3} = h_{t-3} + i\,h_{t-2} + i\frac{i+1}{2}\,h_{t-1} \\
\quad + i\frac{i+1}{2}\frac{i+2}{3}\left(h_t - \frac{i+3}{4}\right); \\
. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \\
h^{(i)}_1 = h_1 + i\,h_2 + i\frac{i+1}{2}\,h_3 + i\frac{i+1}{2}\frac{i+2}{3}h_4 + \ldots \\
\quad + i\frac{i+1}{2}\frac{i+2}{3}\ldots\frac{i+t-2}{t-1}\left(h_t - \frac{i+t-1}{t}\right).
\end{array}\right\} \quad (244.)$$

And making, in these expressions,

$$i = h_t, \quad . \quad . \quad . \quad (245.)$$

so as to have

$$h^{(i)}_t = 0, \quad . \quad . \quad . \quad (246.)$$

and putting, for abridgement,

$$h^{(h_t)}_1 = {}^{\backprime}h_1,\ h^{(h_t)}_2 = {}^{\backprime}h_2, \ldots h^{(h_t)}_{t-1} = {}^{\backprime}h_{t-1}, \quad . \quad . \quad . \quad (247.)$$

we find that at the stage when all the equations of the tth degree have been removed from the auxiliary groups of equations, we are led to satisfy, if possible, by the ratios of $m - h_t$ auxiliary quantities, a system containing $`h_1$ equations of the first degree, $`h_2$ of the second, $`h_3$ of the third, and so on as far as $`h_{t-1}$ of the degree $t - 1$; in which

$$\left.\begin{aligned}
&`h_{t-1} = h_{t-1} + \tfrac{1}{2} h_t (h_t - 1), \\
&`h_{t-2} = h_{t-2} + h_t h_{t-1} + \tfrac{1}{3} (h_t + 1) h_t (h_t - 1), \\
&`h_{t-3} = h_{t-3} + h_t h_{t-2} + \tfrac{1}{2} (h_t + 1) h_t h_{t-1} \\
&\quad + \tfrac{1}{8} (h_t + 2)(h_t + 1) h_t (h_t - 1), \\
&`h_1 = h_1 + h_t h_2 + \tfrac{1}{2} (h_t + 1) h_t h_3 \\
&\quad + \tfrac{1}{6} (h_t + 2)(h_t + 1) h_t h_4 + \dots \\
&\quad + \frac{1}{2.3.4..(t-2)t} (h_t + t - 2)(h_t + t - 3) \dots h_t (h_t - 1);
\end{aligned}\right\} \quad (248.)$$

so that, at this stage, we arrive at the following condition of inequality,

$$m - h_t > `h_1 + `h_2 + `h_3 + .. + `h_{t-1}, \quad . \quad . \quad . \quad . \quad . \quad (249.)$$

$`h_1, `h_2, .. `h_{t-1}$ having the meanings (248). In exactly the same way, we find the condition

$$m - h_t - `h_{t-1} > ``h_1 + ``h_2 + ``h_3 + \dots + ``h_{t-2}, \quad . \quad . \quad (250.)$$

in which,

$$\left.\begin{aligned}
&``h_{t-2} = `h_{t-2} + \tfrac{1}{2} `h_{t-1} (`h_{t-1} - 1), \\
&``h_{t-3} = `h_{t-3} + `h_{t-1} `h_{t-2} \\
&\qquad + \tfrac{1}{3} (`h_{t-1} + 1) `h_{t-1} (`h_{t-1} - 1), \\
&\&c.,
\end{aligned}\right\} \quad . \quad . \quad (251.)$$

by clearing the auxiliary systems from all equations of the degree $t - 1$; and again by clearing all such auxiliary groups from equations of the degree $t - 2$, we obtain a condition of the form

$$m - h_t - `h_{t-1} - ``h_{t-2} > ```h_1 + \dots + ```h_{t-3}, \quad . \quad . \quad (252.)$$

in which

$$```h_{t-3} = ``h_{t-3} + \tfrac{1}{2} ``h_{t-2} (``h_{t-2} - 1), \ \&c. \quad . \quad . \quad (253.)$$

so that at last we are conducted to a condition which may be thus denoted, and which contains the ultimate result of all the restrictions on the number m,

$$m - h_t - {}^{\backprime}h_{t-1} - {}^{\backprime\backprime}h_{t-2} - {}^{\backprime\backprime\backprime}h_{t-3} - \ldots - {}^{(t-2)}h_2 > {}^{(t-1)}h_1, \quad (254.)$$

that is,

$$m > h_t + {}^{\backprime}h_{t-1} + {}^{\backprime\backprime}h_{t-2} + {}^{\backprime\backprime\backprime}h_{t-3} + \ldots + {}^{(t-2)}h_2 + {}^{(t-1)}h_1. \quad (255.)$$

The number m, of quantities originally disposable, must therefore in general be at least equal to a certain minor limit, which may be thus denoted,

$$\left. \begin{aligned} m(h_1, h_2, h_3, \ldots h_t) = h_t + {}^{\backprime}h_{t-1} + {}^{\backprime\backprime}h_{t-2} + \ldots \\ + {}^{(t-2)}h_2 + {}^{(t-1)}h_1 + 1, \end{aligned} \right\} \quad (256.)$$

in order that the method may succeed; and reciprocally, *the method will in general be successful when m equals or surpasses this limit.*

[15.] To illustrate the foregoing general discussion, let us suppose that

$$t = 2; \quad \ldots \ldots \quad (257.)$$

that is, let us propose to satisfy a system containing h_1 equations of the first degree,

$$A' = 0, \ldots A^{(\alpha)} = 0, \ldots A^{(h_1)} = 0, \quad \ldots \quad (193.)$$

and h_2 equations of the second degree,

$$B' = 0, \ldots B^{(\beta)} = 0, \ldots B^{(h_2)} = 0, \quad \ldots \quad (194.)$$

(but not containing any equations of higher degrees than the second,) by a suitable selection of the $m - 1$ ratios of m quantities,

$$a_1, \ldots a_m, \quad \ldots \ldots \quad (192.)$$

and without being obliged in any part of the process to introduce any elevation of degree by elimination. Assuming, as before,

$$a_1 = a'_1 + a''_1, \ldots a_m = a'_m + a''_m, \quad \ldots \quad (197.)$$

and employing the corresponding decompositions

$$A' = A'_{1,0} + A'_{0,1}, \ldots A^{(h_1)} = A^{(h_1)}_{1,0} + A^{(h_1)}_{0,1}, \quad \ldots \quad (258.)$$

and

$$\left. \begin{aligned} B' &= B'_{2,0} + B'_{1,1} + B'_{0,2}, \ldots \\ B^{(h_2-1)} &= B^{(h_2-1)}_{2,0} + B^{(h_2-1)}_{1,1} + B^{(h_2-1)}_{0,2}, \end{aligned} \right\} \quad \ldots \quad (259.)$$

we shall be able to resolve the original problem, if we can resolve the system of the three following.

First: to satisfy, by ratios of the m auxiliary quantities

$$a'_1, \ldots a'_m, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (204)$$

an auxiliary system, containing the h_1 equations of the first degree

$$A'_{1,0} = 0, \ldots A^{(h_1)}_{1,0} = 0, \quad . \quad . \quad . \quad (206)$$

and the $h_2 - 1$ equations of the second degree

$$B'_{2,0} = 0, \ldots B^{(h_2 - 1)}_{2,0} = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (260.)$$

Second: to satisfy, by ratios of the m other auxiliary quantities

$$a''_1, \ldots a''_m, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (205)$$

another auxiliary system, containing $h_1 + h_2 - 1$ equations of the first degree,

$$\left.\begin{array}{l} A'_{0,1} = 0, \ldots A^{(h_1)}_{0,1} = 0, \\ B'_{1,1} = 0, \ldots B^{(h_2 - 1)}_{1,1} = 0, \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (261.)$$

and $h_2 - 1$ equations of the second degree,

$$B'_{0,2} = 0, \ldots B^{(h_2 - 1)}_{0,2} = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (262.)$$

Third: to satisfy, by the ratio of any one of the m quantities (205) to any one of the m quantities (204), this one remaining equation of the second degree

$$B^{(h_2)} = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (263.)$$

The enunciation of the original problem supposes that

$$m > h_1 + h_2; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (264.)$$

since otherwise the original equations (193) and (194) would in general conduct to the excluded case, or case of failure,

$$a_1 = 0, \ldots a_m = 0. \quad . \quad . \quad . \quad . \quad . \quad (216.)$$

In virtue of this condition (264), the first auxiliary problem is indeterminate, because

$$m - 1 > h_1 + h_2 - 1. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (265.)$$

But, by whatever system of ratios

$$\frac{a'_1}{a'_m}, \ldots \frac{a'_{m-1}}{a'_m} \quad . \quad . \quad . \quad . \quad . \quad . \quad (219.)$$

we may succeed in satisfying the first auxiliary system of equations, (206) and (260), we may in general transform the second

auxiliary system of equations, (261) and (262), into a system which may be thus denoted,

$$\left.\begin{aligned} &A^{v}_{0,1} = 0, \ldots A^{v(h_1)}_{0,1} = 0, \\ &B^{v}_{1,1} = 0, \ldots B^{v(h_2-1)}_{1,1} = 0, \\ &B^{v}_{0,2} = 0, \ldots B^{v(h_2-1)}_{0,2} = 0, \end{aligned}\right\} \quad \ldots \ldots \quad (266.)$$

and which contains $h_1 + h_2 - 1$ equations of the first degree, and $h_2 - 1$ equations of the second degree, between the $m - 1$ new combinations, or new auxiliary quantities following,

$$b_1 = a''_1 - \frac{a'_1}{a'_m} a''_m, \ldots b_{m-1} = a''_{m-1} - \frac{a'_{m-1}}{a'_m} a''_m; \quad (267.)$$

so that the solution of the second auxiliary problem will give, in general,

$$b_1 = 0, \ldots b_{m-1} = 0, \quad \ldots \ldots \quad (231.)$$

and therefore will give, for the m auxiliary quantities (205), a system of ratios coincident with the ratios (219),

$$\frac{a''_1}{a''_m} = \frac{a'_1}{a'_m}, \ldots \frac{a''_{m-1}}{a''_m} = \frac{a'_{m-1}}{a'_m}, \quad \ldots \ldots \quad (268.)$$

unless

$$m - 1 > h_1 + 2(h_2 - 1). \quad \ldots \ldots \quad (269.)$$

When, therefore, this last condition is not satisfied, the two first auxiliary problems will conduct, in general, to a system of determined ratios for the m original quantities (192), namely

$$\frac{a_1}{a_m} = \frac{a'_1}{a'_m}, \ldots \frac{a_{m-1}}{a_m} = \frac{a'_{m-1}}{a'_m}; \quad \ldots \quad (218.)$$

and unless these happen to satisfy the equation of the third auxiliary problem, namely

$$B^{(h_2)} = 0, \quad \ldots \ldots \quad (263.)$$

which had not been employed in determining them, we shall fall back on the excluded case, or case of failure, (216). But, even when the condition (269) is satisfied, and when, therefore, the auxiliary equations are theoretically capable of conducting to ratios which shall satisfy the equations originally proposed, it will still be necessary, in general, to decompose each of the two first auxiliary systems of equations into others, in order to comply with the enunciation of the original problem, which requires that we should avoid all raising of degree by elimination,

in every part of the process. Confining ourselves to the consideration of the second auxiliary problem, (which includes the difficulties of the first,) we see that the transformed auxiliary system (266) contains h'_1 equations of the first degree, and h'_2 of the second, if we put, for abridgement,

$$\left.\begin{aligned} h'_2 &= h_2 - 1, \\ h'_1 &= h_1 + h_2 - 1; \end{aligned}\right\} \quad \text{. . . . . . . (270.)}$$

which new auxiliary equations are to be satisfied, if possible, by the ratios of $m - 1$ new auxiliary quantities; so that a repetition of the former process of decomposition and transformation would conduct to a new auxiliary system, containing h''_1 equations of the first degree, and h''_2 of the second, in which

$$\left.\begin{aligned} h''_2 &= h'_2 - 1, \\ h''_1 &= h'_1 + h'_2 - 1, \end{aligned}\right\} \quad \text{. . . . . . (271.)}$$

and which must be satisfied, if possible, by the ratios of $m - 2$ new auxiliary quantities; and thus we should arrive at this new condition, as necessary to the success of the method:

$$m - 2 > h'_1 + 2\,(h'_2 - 1); \quad \text{. . . . . . . (272.)}$$

or, more concisely,

$$m - 2 > h''_1 + h''_2. \quad \text{. . . . . (273.)}$$

And so proceeding, we should find generally,

$$m - i > h_1^{(i)} + h_2^{(i)}, \quad \text{. . . . . (274.)}$$

the functions $h_1^{(i)}$, $h_2^{(i)}$ being determined by the equations

$$h_2^{(o)} = h_2,\ h_1^{(o)} = h_1, \quad \text{. . . . . (275.)}$$

$$h_2^{(i+1)} - h_2^{(i)} = -1, \quad \text{. . . . . (276.)}$$

$$h_1^{(i+1)} - h_1^{(i)} = h_2^{(i+1)}; \quad \text{. . . . . . (277.)}$$

which give, by integrations of finite differences,

$$\left.\begin{aligned} h_2^{(i)} &= h_2 - i; \\ h_1^{(i)} &= h_1 + i\left(h_2 - \frac{i+1}{2}\right). \end{aligned}\right\} \quad \text{. . . (278.)}$$

Thus, making

$$i = h_2, \quad \text{. . . . . (279.)}$$

and putting, for abridgement,

$$`h_1 = h_1^{(h_2)} = h_1 + \tfrac{1}{2}\,h_2\,(h_2 - 1), \quad \text{. . . . . . (280.)}$$

we arrive at last at a stage of the process at which we have to satisfy a system of $`h_1$ equations of the first degree by the ratios of $m - h_2$ quantities; and now, at length, we deduce this final

condition of inequality, to be satisfied by the number m, in order to the general success of the method (in the case $t = 2$),

$$m - h_2 > h_1; \quad \ldots \ldots \quad (281.)$$

that is,

$$m > h_1 + \tfrac{1}{2}(h_2 + 1) h_2; \quad \ldots \ldots \quad (282.)$$

or, in other words, m must at least be equal to the following *minor limit*,

$$m(h_1, h_2) = h_1 + 1 + \tfrac{1}{2}(h_2 + 1) h_2. \quad \ldots \ldots \quad (283.)$$

For example, making $h_1 = 1$, and $h_2 = 2$, we find that a system containing *one* homogeneous equation of the first degree, and *two* of the second, can be satisfied, in general, without any elevation of degree by elimination, and therefore without its being necessary to resolve any equation higher than the second degree, by the ratios of m quantities, provided that this number m is not less than the minor limit *five*: a result which may be briefly thus expressed,

$$m(1, 2) = 5. \quad \ldots \ldots \quad (284.)$$

[16.] Indeed, it might seem, that in the process last described, an advantage would be gained by stopping at that stage, at which, by making $i = h_2 - 1$ in the formulæ (278), we should have

$$\left.\begin{array}{l} h_2^{(h_2 - 1)} = 1, \\ h_1^{(h_2 - 1)} = h_1 + \tfrac{1}{2} h_2 (h_2 - 1), \end{array}\right\} \quad \ldots \ldots \quad (285.)$$

and

$$m - i = m - h_2 + 1; \quad \ldots \ldots \quad (286.)$$

that is, when we should have to satisfy, by the ratios of $m - h_2 + 1$ quantities, a system containing only *one* equation of the second degree, in combination with $h_1 + \frac{1}{2} h_2 (h_2 - 1)$ of the first. For, the ordinary process of elimination, performed between the equations of this last system, would not conduct to any equation higher than the second degree; and hence, without going any further, we might perceive it to be sufficient that the number m should satisfy this condition of inequality,

$$m - h_2 + 1 > h_1 + \tfrac{1}{2} h_2 (h_2 - 1) + 1. \quad \ldots \quad (287.)$$

But it is easy to see that this alteration of method introduces no real simplification; the condition (287) being really coincident with the condition (282) or (283). To illustrate this result, it may be worth observing, that, in general, instead of the ordinary mode of satisfying, by ordinary elimination, any system of rational and integral and homogeneous equations, containing n such equations of the first degree,

$$`A' = 0, `A'' = 0, \dots `A^{(n)} = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad (288.)$$

and one of the second degree,

$$`B' = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (289.)$$

by the $n + 1$ ratios of $n + 2$ disposable quantities,

$$a_1, a_2, \dots a_{n+2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (290.)$$

it is permitted to proceed as follows. Decomposing each of the first $n + 1$ quantities into two parts, so as to put

$$a_1 = a'_1 + a''_1, a_2 = a'_1 + a''_2, \dots a_{n+1} = a'_{n+1} + a''_{n+1}, \quad (291.)$$

we may decompose each of the given functions of the first degree, such as $`A^{(\alpha)}$, into two corresponding parts, $`A^{(\alpha)}_{1,0}$ and $`A^{(\alpha)}_{0,1}$, of which the former, $`A^{(\alpha)}_{1,0}$, is a function of the first degree of the $n + 2$ quantities,

$$a'_1, a'_2, \dots a'_{n+1}, a'_{n+2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (292.)$$

while the latter, $`A^{(\alpha)}_{0,1}$, is a function of the first degree of the $n + 1$ other quantities

$$a''_1, a''_2, \dots a''_{n+1}; \quad . \quad . \quad . \quad . \quad . \quad . \quad (293.)$$

and then, after resolving in any manner the indeterminate problem, to satisfy the n equations of the first degree,

$$`A'_{1,0} = 0, `A''_{1,0} = 0, \dots `A^{(n)}_{1,0} = 0, \quad . \quad . \quad . \quad . \quad . \quad (294.)$$

by a suitable selection of the $n + 1$ ratios of the $n + 2$ quantities (292), (excluding only the assumption $a_{n+2} = 0$,) we may determine the n ratios of the $n + 1$ quantities (293), so as to satisfy these n other equations of the first degree,

$$`A'_{0,1} = 0, `A''_{0,1} = 0, \dots `A^{(n)}_{0,1} = 0; \quad . \quad . \quad . \quad . \quad . \quad (295.)$$

after which it will only remain to determine the ratio of any one of these latter quantities (293) to any one of the former quantities (292), so as to satisfy the equation of the second degree (289), and the original problem will be resolved.

[17.] Again, let

$$t = 3; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (296.)$$

that is, let us consider a system containing h_1 equations of the first degree, such as those marked (193), along with h_2 equations

of the second degree (194), and h_3 equations of the third degree (195), to be satisfied by the ratios of m disposable quantities (192). After exhausting, by the general process already sufficiently explained, all the equations of the third degree in all the auxiliary systems, we are conducted to satisfy, if possible, by the ratios of $m - h_3$ quantities, a system containing ${}'h_1$ equations of the first, and ${}'h_2$ of the second degree, in which,

$$\left.\begin{aligned} {}'h_2 &= h_2 + \tfrac{1}{2} h_3 (h_3 - 1), \\ {}'h_1 &= h_1 + h_3 h_2 + \tfrac{1}{3} (h_3 + 1) h_3 (h_3 - 1); \end{aligned}\right\} \quad . \quad . \quad (297.)$$

and after exhausting, next, all the equations of the second degree in all the new auxiliary systems, we are conducted to satisfy, by the ratios of $m - h_3 - {}'h_2$ quantities, a system of ${}''h_1$ equations of the first degree, in which,

$${}''h_1 = {}'h_1 + \tfrac{1}{2}\, {}'h_2 ({}'h_2 - 1). \quad . \quad . \quad . \quad . \quad . \quad (298.)$$

We find, therefore, that the number m must satisfy the following condition of inequality,

$$m - h_3 - {}'h_2 > {}''h_1, \quad . \quad . \quad . \quad . \quad . \quad (299.)$$

that is,

$$m > h_3 + {}'h_2 + {}''h_1. \quad . \quad . \quad . \quad . \quad . \quad (300.)$$

On substituting for ${}''h_1$ its value (298), this last condition becomes,

$$m > h_3 + \tfrac{1}{2}\, {}'h_2 ({}'h_2 + 1) + {}'h_1; \quad . \quad . \quad . \quad . \quad . \quad (301.)$$

that is, in virtue of the expressions (297),

$$\left.\begin{aligned} m > h_1 &+ \tfrac{1}{2} (h_2 + 1) h_2 + \tfrac{1}{2} (h_2 + 1)(h_3 + 1) h_3 \\ &+ \tfrac{1}{3} (h_3 + 1) h_3 (h_3 - 1) + \tfrac{1}{8} (h_3 + 1) h_3 (h_3 - 1)(h_3 - 2.) \end{aligned}\right\} \quad (302.)$$

The number m must therefore equal or surpass a certain minor limit, which, in the notation of factorials, may be expressed as follows:

$$\left.\begin{aligned} m \not< (h_1 + 1) &+ \tfrac{1}{2} [h_2 + 1]^2 + \tfrac{1}{2} (h_2 + 1) [h_3 + 1]^2 \\ &+ \tfrac{1}{3} [h_3 + 1]^3 + \tfrac{1}{8} [h_3 + 1]^4; \end{aligned}\right\} \quad . \quad . \quad (303.)$$

the symbol $[\eta]^n$ denoting the continued product,

$$[\eta]^n = \eta (\eta - 1)(\eta - 2) \ldots (\eta - n + 1). \quad . \quad . \quad . \quad (304.)$$

So that when we denote this minor limit of m by the symbol $m(h_1, h_2, h_3)$, we obtain, in general, the formula

$$m(h_1, h_2, h_3) = \eta_1 + \tfrac{1}{2} [\eta_2]^2 + \tfrac{1}{2} \eta_2 [\eta_3]^2 + \tfrac{1}{3} [\eta_3]^3 + \tfrac{1}{8} [\eta_3]^4, \quad (305.)$$

in which,

$$\eta_1 = h_1 + 1,\ \eta_2 = h_2 + 1,\ \eta_3 = h_3 + 1 \ldots \qquad (306.)$$

For example,

$$m\,(1, 1, 1) = 5. \qquad (307.)$$

[18.] When

$$t = 4, \qquad (308.)$$

that is, when some of the original equations are as high as the fourth degree, (but none more elevated,) then

$$\left.\begin{array}{l} 'h_3 = h_3 + \frac{1}{2} h_4 (h_4 - 1), \\ 'h_2 = h_2 + h_4 h_3 + \frac{1}{3} (h_4 + 1) h_4 (h_4 - 1), \\ 'h_1 = h_1 + h_4 h_2 + \frac{1}{2} (h_4 + 1) (h_4 h_3 \\ \qquad + \frac{1}{8} (h_4 + 2) (h_4 + 1) h_4 (h_4 - 1); \end{array}\right\} \qquad (309.)$$

$$\left.\begin{array}{l} ''h_2 = 'h_2 + \frac{1}{2}\, 'h_3 ('h_3 - 1), \\ ''h_1 = 'h_1 + 'h_3\, 'h_2 + \frac{1}{3} ('h_3 + 1)\, 'h_3 ('h_3 - 1); \end{array}\right\} \qquad (310.)$$

$$'''h_1 = ''h_1 + \frac{1}{2}\, ''h_2 (''h_2 - 1); \qquad (311.)$$

and the minor limit of m, denoted by the symbol $m\,(h_1, h_2, h_3, h_4)$, is given by the equation

$$m\,(h_1, h_2, h_3, h_4) = h_4 + 'h_3 + ''h_2 + '''h_1 + 1; \qquad (312.)$$

which may be thus developed,

$$\left.\begin{array}{l} m\,(h_1, h_2, h_3, h_4) = \eta_1 + \frac{1}{2} [\eta_2]^2 + \frac{1}{2} \eta_2 [\eta_3]^2 \\ \quad + \frac{1}{3} [\eta_3]^3 + \frac{1}{8} [\eta_3]^4 \\ + \eta_2 \left\{ \frac{1}{2} \eta_3 [\eta_4]^2 + \frac{1}{3} [\eta_4]^3 + \frac{1}{8} [\eta_4]^4 \right\} \\ + \frac{1}{4} [\eta_3]^3 [\eta_4]^2 + [\eta_3]^2 \left\{ \frac{1}{2} [\eta_4]^2 + \frac{2}{3} [\eta_4]^3 + \frac{3}{16} [\eta_4]^4 \right\} \\ + \eta_3 \left\{ [\eta_4]^3 + \frac{7}{4} [\eta_4]^4 + \frac{2}{3} [\eta_4]^5 + \frac{1}{16} [\eta_4]^6 \right\} \\ + \frac{3}{2} [\eta_4]^4 + \frac{5}{2} [\eta_4]^5 + \frac{79}{72} [\eta_4]^6 + \frac{1}{6} [\eta_4]^7 + \frac{1}{128} [\eta_4]^8, \end{array}\right\} (313.)$$

if we employ the notation of factorials, and put for abridgement,

$$\eta_1 = h_1 + 1, \ldots \eta_4 = h_4 + 1. \qquad (314.)$$

In the notation of powers, we have

$$\left.\begin{aligned} m(h_1, h_2, h_3, h_4) &= 1 + h_1 \\ &+ \frac{1}{24} h_2 (12 + 10\, h_4 + 9\, h_4^2 + 2\, h_4^3 + 3\, h_4^4) \\ &+ \frac{1}{2} h_2 h_3 (1 + h_4 + h_4^2) + \frac{1}{2} h_2 h_3^2 + \frac{1}{2} h_2^2 \\ &+ \frac{1}{48} h_3 (20 + 22\, h_4 + 25\, h_4^2 + 9\, h_4^3 \\ &\quad + 8\, h_4^4 + 5\, h_4^5 + 3\, h_4^6) \\ &+ \frac{1}{48} h_3^2 (18 + 10\, h_4 + 15\, h_4^2 + 14\, h_4^3 + 9\, h_4^4) \\ &+ \frac{1}{12} h_3^3 (1 + 3\, h_4 + 3\, h_4^2) + \frac{1}{8} h_3^4 \\ &+ \frac{1}{1152} (432\, h_4 + 364\, h_4^2 + 108\, h_4^3 + 169\, h_4^4 \\ &\quad + 24\, h_4^5 + 34\, h_4^6 + 12\, h_4^7 + 9\, h_4^8). \end{aligned}\right\} \quad (315.)$$

As examples, whichever formula we employ, we find

$$m(1, 0, 1, 1) = 7; \quad \ldots \quad (316.)$$

$$m(1, 1, 1, 1) = 11; \quad \ldots \quad (317.)$$

$$m(1, 1, 1, 2) = 47; \quad \ldots \quad (318.)$$

$$m(5, 4, 3, 3) = 922. \quad \ldots \quad (319.)$$

[19.] In general (by the nature of the process explained in the foregoing articles) the minor limit (256) of the number m, which we have denoted by the symbol

$$m(h_1, h_2, \ldots h_t),$$

is a function such that

$$m(h_1, h_2, \ldots h_t) = 1 + m(h'_1, h'_2, \ldots h'_t), \quad \ldots \quad (320.)$$

$h'_1, \ldots h'_t$ being determined by the formulæ (233). This equation in finite differences (320) may be regarded as containing the most essential element of the whole foregoing discussion; and from it the formulæ already found for the cases $t = 2$, $t = 3$, $t = 4$, might have been deduced in other ways. From it also we may perceive, that whenever the original system contains only one equation of the highest or tth degree, in such a manner that

$$h_t = 1, \quad \ldots \quad (321.)$$

then, whatever t may be, we have the formula

$$\left.\begin{array}{l} m(h_1, h_2, \ldots h_{t-1}, 1) \\ \quad = 1 + m(h_1 + h_2 + \ldots + h_{t-1}, h_2 + \ldots + h_{t-1}, \ldots h_{t-1}); \end{array}\right\} \quad (322.)$$

so that, for example,

$$m(1,1,1,1,1) = 1 + m(4,3,2,1); \quad \ldots \quad (323.)$$

$$m(4,3,2,1) = 1 + m(9,5,2) = 46; \quad \ldots \quad (324.)$$

$$m(1,1,1,1,1,1) = 1 + m(5,4,3,2,1); \quad \ldots \quad (325.)$$

$$m(5,4,3,2,1) = 1 + m(14,9,5,2) = 922; \quad \ldots \quad (326.)$$

and therefore

$$m(1,1,1,1,1) = 47, \quad \ldots \quad (327.)$$

and

$$m(1,1,1,1,1,1) = 923. \quad \ldots \quad (328.)$$

[20.] The formula

$$m(1,1,1) = 5, \quad \ldots \quad (307.)$$

may be considered as expressing, generally, that in order to satisfy a system of three homogeneous equations, rational and integral, and of the forms

$$A' = 0, \; B' = 0, \; C' = 0, \quad \ldots \quad (329.)$$

that is, of the first, second, and third degrees, by a system of ratios of m disposable quantities

$$a_1, \ldots a_m, \quad \ldots \quad (192.)$$

which ratios are to be discovered by Mr. Jerrard's method of decomposition, without any elevation of degree by elimination, the number m ought to be at least equal to the minor limit *five*; a result which includes and illustrates that obtained in the 4th article of the present communication, respecting Mr. Jerrard's process for *taking away three terms* at once from the general equation of the mth degree: namely that this process is not generally applicable when m is less than *five*. Again, the process described in the eleventh article, for taking away, on Mr. Jerrard's principles, *four terms* at once from the general equation of the mth degree, without being obliged to eliminate between any two equations of condition of higher degrees than the first, was shown to require, for its success, in general, that m should be at least equal to the minor limit *eleven*; and this limitation is included in, and illustrated by, the result

$$m(1,1,1,1) = 11, \quad \ldots \quad (317.)$$

which expresses generally a similar limitation to the analogous process for satisfying any four homogeneous equations of condition,

$$A' = 0, B' = 0, C' = 0, D' = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad (330.)$$

of the first, second, third, and fourth degrees, by the ratios of m disposable quantities, $a_1, a_2, \ldots a_m$. In like manner it is shown by the result

$$m(1, 1, 1, 1, 1) = 47, \quad . \quad . \quad . \quad . \quad . \quad . \quad (327.)$$

that Mr. Jerrard's general method would not avail to satisfy the five conditions

$$A' = 0, B' = 0, C' = 0, D' = 0, E' = 0, \quad . \quad . \quad (331.)$$

and so to take away *five terms* at once from the equation of the mth degree, without any elevation of degree being introduced in the eliminations, unless m be at least $= 47$, that is, unless the equation to be transformed be at least of the 47th degree; and the result

$$m(1, 1, 1, 1, 1, 1) = 923, \quad . \quad . \quad . \quad . \quad . \quad (328.)$$

shows that the analogous process for taking away *six terms* at once, or for satisfying the six conditions

$$A' = 0, B' = 0, C' = 0, D' = 0, E' = 0, F' = 0, \quad . \quad (332.)$$

is limited to equations of the 923rd and higher degrees.

Finally, the result

$$m(1, 0, 1, 1) = 7, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (316.)$$

and the connected result

$$m(1, 0, 1, 0, 1) = 7, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (333.)$$

show that it is not in general possible to satisfy, by the same method, a system of three conditions of the first, third, and fourth degrees, respectively, such as the system

$$A' = 0, C' = 0, D' - \alpha B'^2 = 0, \quad . \quad . \quad . \quad . \quad . \quad (334.)$$

nor a system of 3 conditions of the first, third, and fifth degrees,

$$A' = 0, C' = 0, E' = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (335.)$$

unless m be at least $= 7$; which illustrates and confirms the conclusions before obtained respecting the inadequacy of the method to reduce the general equation of the fifth degree to De Moivre's solvible form, or to reduce the general equation of the sixth to that of the fifth degree.

[21.] Indeed, if *some* elevation of degree be admitted in the eliminations between the auxiliary equations, the minor limit of the number m may sometimes be advantageously depressed. Thus, in the process for satisfying the system of equations (330), we first reduce the original difficulty to that of satisfying, by the ratios of $m - 1$ quantities, a system containing three equations

of the first degree, two of the second, and one of the third; and we next reduce this difficulty to that of satisfying, by the ratios of $m - 2$ quantities, a system containing five equations of the first, and two of the second degree. Now, at this stage, it is advantageous to depart from the general method, and to have recourse to ordinary elimination; because we can thus resolve the last-mentioned auxiliary system, not indeed without *some* elevation of degree, but with an elevation which conducts no higher than a biquadratic equation; and by avoiding the additional decomposition which the unmodified method requires, we are able to employ a lower limit for m. In fact, the general method would have led us to a new transformation of the question, by which it would have been required to satisfy, by the ratios of $m - 3$ new quantities, a system containing six new equations of the first, and one of the second degree; it would therefore have been necessary, in general, in employing that method, that $m - 3$ should be greater than $6 + 1$, or in other words that m should be at least equal to the minor limit *eleven*; and accordingly we found

$$m(1, 1, 1, 1) = 11. \quad . \quad . \quad . \quad (317.)$$

But when we dispense with this last decomposition, we need only have $m - 2 > 5 + 2$, and the process, by this modification, succeeds even for $m =$ *ten*. It was thus that Mr. Jerrard's principles were shown, in the tenth article of this paper, to furnish a process for taking away four terms at once from equations as low as the tenth degree, provided that we employ (as we may) certain auxiliary systems of conditions, (160) and (161), of which each contains two equations of the second degree, but none of a degree more elevated. But it appears to be impossible, by any such mixture of ordinary elimination with the general method explained above, to depress so far that lower limit of m which has been assigned by the foregoing discussion, as to render the method available for *resolving* any general equation, by reducing it to any known solvible form. This *Method of Decomposition* has, however, conducted, in the hands of its inventor Mr. Jerrard, to several general *transformations* of equations, which must be considered as discoveries in algebra; and to the solution of an extensive class of problems in the analysis of *indeterminates*, which had not before been resolved: the *notation*, also, of *symmetric functions*, which has been employed by that mathematician, in his published researches* on these subjects, is one of great beauty and power.

* *Mathematical Researches*, by George B. Jerrard, A.B., Bristol; printed by William Strong, Clare Street; to be had of Longman and Co., London.

NOTICES

AND

ABSTRACTS OF COMMUNICATIONS

TO THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE,

AT THE

BRISTOL MEETING, AUGUST 1836.

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The Editors of the following Notices consider themselves responsible only for the fidelity with which the views of the Authors are abstracted.

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TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

A brief Account of some Researches in the Integral Calculus. By H. F. Talbot, *Esq.*

Having been asked to lay before the British Association a notice of my researches in the Integral Calculus, so far as they have been published in the Philosophical Transactions for the present year, I have drawn up a short account of this subject.

Upwards of one hundred years ago, an Italian geometer, Fagnani, discovered that *the difference* of two elliptic arcs is in some cases accurately equal to a straight line, whose length is known; although neither of the arcs, taken separately, can be so expressed. Thus he found, for example, that the quadrant of every ellipse is capable of being so bisected that the difference of the parts is equal to the difference of the major and minor axis of the curve. He also found that the hyperbola possesses similar properties, and also the lemniscate, and several other curves. He thus with great ingenuity and sagacity opened a new track in the regions of analysis, the existence of which had until his time remained unknown.

The next considerable step was made by Euler, who showed generally that the sum of the two integrals $\int \frac{d\,x}{\sqrt{\mathrm{X}}} + \int \frac{d\,y}{\sqrt{\mathrm{Y}}}$ may be always rendered equal to a constant, by assuming a proper equation between the variables x and y, provided that X was a polynomial in x not exceeding the fourth degree. But if X contained the fifth or higher powers of x, he was unable (except in very special cases) to find any solution of the problem.

Lagrange, who also endeavoured to remove this difficulty, met with no better success.

The reason of the failure appears now to be manifest, that the solution of the problem was sought for in the wrong direction. It was attempted always to combine *two* integrals into an algebraic

sum, which can only be done successfully in certain cases. In all other cases it is requisite to combine three or more integrals, and the idea of doing this seems not to have occurred to these illustrious analysts.

Thus, for instance, they tried in vain to find the *algebraic* integral of the equation $\int \frac{d\,x}{\sqrt{1+x^5}} + \int \frac{d\,y}{\sqrt{1+y^5}} = 0$.

But if they had sought for the algebraic integral of

$$\int \frac{d\,x}{\sqrt{1+x^5}} + \int \frac{d\,y}{\sqrt{1+y^5}} + \int \frac{d\,z}{\sqrt{1+z^5}} = 0.$$

they would have found that such a solution really exists.

However, the theorem which Euler gave, although limited in its extent, yet proved to be of great importance, and may be considered the foundation of the theory of elliptic functions given by Legendre, the different properties of which are implicitly contained in Euler's solution, although Legendre's talents and industry were requisite to draw them forth, and develop them with clearness and precision.

While examining this subject in the year 1825, I met with a new property of the equilateral hyperbola, which appeared to me to be of great importance, as it gave the algebraic sum of *three* arcs of that curve.

If the abscissæ of the three arcs are the roots of a cubic equation, of this particular form, viz.: $x^3 - \frac{r^2}{4}\,x - r = 0$, I found that the sum of the arcs was an algebraic quantity. In this equation the letter r is arbitrary. Each particular value which is attributed to it furnishes a solution of the problem, that is, it gives three arcs whose sum is algebraic.

I verified the truth of this theorem by numerical computations of different examples of it, but in so doing I met with two difficulties of a novel nature. The first was, that by attributing certain values to r, the cubic equation had two impossible roots, and the theorem then apparently ceased to have any real meaning. (At that time Legendre had not yet demonstrated the fact, that two imaginary integrals can make a real integral by their addition.)

The other difficulty was this, that in making the addition of the three integrals, I found that it was necessary to attribute a negative sign to one of them, and although by making actual trial in each numerical example, it was easy to see which of the integrals had this sign, yet it was by no means so easy to assign a convincing reason why this ought to be the case.

The method which had conducted me to this theorem respecting the equilateral hyperbola, would, as I saw, furnish a multitude of other theorems equally curious; but the field of inquiry was so new, and the results which it afforded at every step so ample, that I was at a loss how to classify them, or reduce them into a clear and connected theory. For instance, I perceived that I might consider n

variables instead of only three, and that I might suppose them connected by the general equation,

$$x^n + a\,x^{n-1} + b\,x^{n-2} + \ldots\ldots = 0,$$

whose coëfficients a, b, &c. are all different functions of an arbitrary quantity r. Then, when any particular value is given to r, the n roots of the equation (or in other words the n variables) become determined as to their numerical value.

And if r changes its value to another value, the n variables severally undergo a corresponding change. Therefore they all vary simultaneously, and the variation of any one of them is a determinate function of the variation of any of the others.

The n variables being connected in this manner, I found that the values of certain integrals which depend upon them might frequently be shown to have an algebraic sum. That is to say, the equation of condition between the variables *being given*, new properties of various integrals were found to be deducible therefrom. But the inverse problem was found to be much more difficult, namely, "*When the form of the integral was given, to discover the equation which ought to be assumed between the variables.*"

This problem is the more important one because it is what occurs in practical applications of the calculus. The solution of it, which I have given in the Transactions of the Royal Society for 1836, appears to me to be as simple as the nature of the problem admits of, and it conducts readily and rapidly to the form of equation which ought to be assumed in any particular instance. And the form of that equation being known, the properties of the integral frequently flow from it with a facility which is surprising, considering the nature and difficulties of the inquiry.

While I was occupied in this investigation, that distinguished mathematician Mr. Abel published a very remarkable theorem, which gives the algebraic sum of a series of integrals of the form $\int \frac{P\,dx}{\sqrt{R}}$, when P and R are polynomials in x *of any degree*.

The methods of reasoning by which he arrived at this theorem appear to have been quite different from those which I pursued, and the form of his solution is altogether different from mine, although in all those instances which I have tried the results ultimately concur (as might be expected). But it will be observed that this celebrated theorem is limited to those forms of integral $\int \frac{P\,dx}{\sqrt{R}}$, where the polynomial R has a quadratic radical.

My method, on the contrary, applies with equal facility to the Cubic Radicals and to those of all higher degrees, as well as to a great many other integral forms of a more complicated nature.

I have therefore proposed to drop the name which Legendre has given, of Ultra-Elliptic Integrals, since it appears that no line of distinction can be drawn between them and integrals in general, which possess similar properties to an extent so much greater than has been hitherto imagined.

In prosecuting further inquiries it will be desirable to consider which are the forms of transcendents which ought to be reckoned as next in order to those whose properties have been hitherto most investigated, viz., to the Circular Logarithmic and Elliptic functions.

It appears to me that the transcendents might be divided and classed according to the number of them which it is requisite to combine in order to obtain an algebraic sum. Thus the transcendent $\int \frac{d\,x}{\sqrt{1+x^5}}$ is of a more complicated nature than $\int \frac{d\,x}{\sqrt{1+x^4}}$, because it is requisite to unite three terms of the former to obtain an algebraic sum, while it suffices to add two terms of the latter one.

According to this view the transcendent $\int \frac{d\,x}{\sqrt{1+x^5}}$ will be the representative of a class whose properties are to be examined by themselves, and which are probably irreductible to transcendents of a lower class. Before, however, occupying ourselves with these, it is well to inquire what results these new methods give when applied to the arcs of the Conic Sections, a subject which was supposed to have been almost exhausted by the labours of Legendre, but which the researches of Jacobi, Abel, and others have shown to be far from being so.

I have found, with respect to my own method, that besides the theorem which I originally met with concerning the sum of three arcs of the Equilateral Hyperbola, it likewise gives a number of other theorems respecting the sums of the arcs of the Conic Sections.

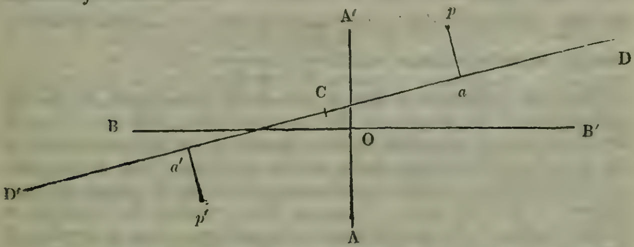
But which of all these theorems are essentially different from each other it requires much time to thoroughly examine. And since it is desirable for the sake of verification, and to avoid falling into errors, to accompany the processes of analysis with numerical examples, these examples, if calculated to six or seven places of decimals, often run into extreme prolixity, and would be best accomplished by the assistance of several independent calculators.

On the Calculus of Principal Relations. By Professor Sir W. R. Hamilton.

The method of principal relations, of which Sir W. Hamilton gave a short explanation, is still more general than the analogous researches in optics and dynamics presented to former meetings of the Association. By it the author proposed to reduce all questions in analysis to one fundamental equation or formula, no matter how numerous the conditions, or the independent variables might be. He has found the following relation, which he has termed principal, to subsist between all differential functions, no matter how numerous, or independent the variables, viz.: $\frac{\delta\,d\,s}{\delta\,d\,x}=\frac{\delta\,s}{\delta\,x}$.

Illustration of the Meaning of the doubtful Algebraic Sign in certain Formulæ of Algebraic Geometry. By Professor STEVELLY.

The author had been led some years since to see the importance of the present question as bearing upon the determination of geometric positions by algebraic symbols, by finding that, when transforming the axes of coordinates, it was sometimes requisite to use the positive sign for the perpendicular let fall from a given point upon a given line, and at other times the negative sign, although no intelligible reason for the difference was assigned in the books, nor could he for a long time give any reason that was satisfactory to his own mind, or which would lead to an unvarying rule. At length, while reflecting upon the origin of this doubtful sign, he was led to a conclusion which was quite satisfactory to himself, and which furnished, he conceived, a complete key to the interpretation of this and many similar cases.



It is well known that if $A\,A'$ and $B\,B'$ be the axes of coordinates, O being the origin, and it be arbitrarily determined to consider distances measured from O towards B' as positive, it is necessary, by the connection between algebraic addition and subtraction, and the increasing and diminishing of such distances, to distinguish by the negative sign all distances measured from O towards B. A similar rule holds for the axis $A\,A'$, and for every other axis passing through O; from hence it can be readily shown that all lines drawn parallel to any fixed line, such as $A\,A'$, and falling upon and terminated by $B\,B'$, must be similarly distinguished; those that fall upon the upper side or face, for example, being supposed to be positive, these falling upon the under side or face, must be marked as negative. A similar rule can be easily shown to hold for any line in the plane of these axes. And this being attended to will inform us why algebra ought to mark with the sign $\pm$, the perpendicular let fall from a point (p) whose coordinates are $(x'\ y')$ upon a line whose equation is $y = a\,x + b$. Although at first we should think that as but one point can have these coordinates, and one line only have that equation, there can be but one perpendicular to whose value we ought to be led; yet, in fact, we find the perpendicular to be $\pm \frac{y' - a\,x' - b}{\sqrt{1 + a^2}}$. The reason why algebra leads

us to this double value is obvious when we consider that all perpendiculars upon one side or face of the given line being considered as positive, all on the opposite side or face must be marked as negative; for if the given line be supposed to revolve in the plane of the coordinates, any point of it being fixed as soon as it has passed through a semirevolution, it will take a position in which the very same equation as at first will belong to it, and in which the perpendicular upon it from the given point p will have exactly the same length; and indeed be the very same line that was perpendicular to it in its first position. In the first position the perpendicular from P falls upon the face of the line which is then turned towards it; but after the semirevolution, the perpendicular from P falls upon the face of the line which, in its first position had been averted from P; and hence one of these perpendiculars is presented to us by the analytic investigation, as $+\frac{y'-ax'-b}{\sqrt{1+a^2}}$, while the other from the same point, P, upon the line expressed still by the same equation, $y-ax-b=o$, is brought under our notice, as, $-\frac{y'-ax'-b}{\sqrt{1+a^2}}$.

That this is the true origin of the double sign found in the investigation of the length of the perpendicular, will be still more clearly seen by tracing the varying length of the perpendicular, as the line D' C D revolves from its first position. Let us suppose, (in order to fix our ideas) round some point, as C, which we may suppose to hold its place. Then as the revolving line approaches P the length of the perpendicular diminishes; when it reaches P that length vanishes; when it passes P the perpendicular now falling on the face that had been at first averted from P, becomes negative; or, rather, has a sign opposite to that which we first attributed to it; and this sign it retains as long as the perpendicular continues to fall on the same face; and therefore, when it has passed through its semirevolution, it retains that contrary sign; but at the end of the semirevolution, the perpendicular is the very same as it was at first, and the line in the new position has the same equation that at first belonged to it; the face alone on which that perpendicular falls has changed, and algebra marks that change by the change of sign of the value of the perpendicular. Indeed, it is easy to see that after the semirevolution is completed, a perpendicular P' A' at an equal distance from C', and similarly situated on the other side from P A, and erected upon the opposite face of the given line, will have come round to the portion of P A, and will then coincide with it, if it be supposed to accompany the revolving line, and to be inflexibly attached to it.

An account nearly the same can be given of the double sign of the distance between two points $(x'y')$ and $(x''y'')$, which, as is well known, is $= \pm \sqrt{(x'-x'')^2+(y'-y'')^2}$. If we at first arbitrarily assume the + value as belonging to the distance: then if a point be made to move from that given point, which is nearest to the origin of

the coordinates, suppose from the point $(x'' y'')$ *towards* the other point, it will, by motion in that direction, describe and increase positive distances; but, by a motion in the contrary direction it would describe or increase negative distances. If we then suppose the indefinite line joining $(x'' y'')$ and $(x' y')$ to revolve slowly round one of these points as a centre, suppose round $(x'' y'')$ the law of continuity will compel us to consider a point moving the same way from the fixed point as describing and increasing negative distances; now, when the revolving line has completed a semirevolution, it will again pass through the second point, $(x' y')$; but a moving point setting off from $(x'' y'')$ must, in order to reach $(x' y')$, move along the indefinite line after its semirevolution, in precisely an opposite direction to that which led to the same point in its first position, and, therefore, the same identical distance must, in this last position, be considered as negative, if, in the first position, we assumed it to be positive; and hence the double sign to which the analytic value directs our attention.

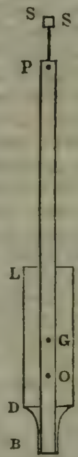
In a similar way we can explain the double sign of the secant of an arch, the opposite sign of the secant of an arch, and of its supplement, and of the same arch increased by a semicircle. We may also see the reason for the double sign of the analytic value of the radius of curvature; and thus many symbols which were formerly not perceived to have any relation to position, will appear to have a very direct and intelligible relation to it; and thus, much that was formerly arbitrary will be rendered subject to precise rules.

On "The Mathematical Rules for constructing Compensating Pendulums." By Professor Stevelly.

Accident led the author to the discovery of an error of serious consequence which he had previously never suspected, in the principle of calculating the dimensions of the several parts of compensating pendulums adopted by Captain Kater, and detailed by him in the latter part of the volume on Mechanics in Lardner's Cyclopædia. Doctor Templeton, of the Royal Artillery, had kindly undertaken to find a meridian line at the apartments of the Museum of the Belfast Natural History Society. When doing so he had used a well-made eight-day clock furnished with a pendulum with a deal rod, which although carefully made had not been intended to compensate for changes of temperature. This pendulum had gone in a room immediately under a leaden roof during a very cold winter, and afterwards during a very hot summer, and yet had not varied more than a very few seconds from mean time, and even that variation had not taken place with any considerable departure from a mean rate of gaining. Surprise at this fact led Mr. Stevelly to perceive that a common deal rod pendulum, with a large lenticular leaden bob resting on a nut, and transfixed by the deal rod, must be to a certain extent compensating. He then proceeded to calculate the exact dimensions for perfect compensation; but upon applying the mathematical principle upon which he had made the calculation to some of the examples given by Captain

Kater, he arrived at dimensions differing so much from those given by that eminent author as to lead him to fear that he had made some gross error in applying the differential calculus to the investigation. A little consideration, however, convinced him that the fundamental principle of Kater's calculation was erroneous.

The erroneous principle virtually adopted by Captain Kater is, that the centre of oscillation of the heavy metallic part of the pendulum retains constantly its relative place in the mass; so that its distance from the lowest part where it is supported by the pendulum rod is to be taken as the length of metal whose expansions and contractions are to compensate those of the rod. Now it is almost obvious that the position of that centre in the mass changes, on two accounts: first, the moment of inertia of the mass which is the numerator of part of the value of the length of the pendulum is changed by the changing of the dimensions of the several parts of the pendulum by changes of temperature; secondly, the distance of the centre of gravity of the mass from the axis of suspension changes also, and it enters as a denominator into the same value. These combined causes produce a change of great practical consequence in the position of the centre of oscillation during alterations of temperature.



Time permitted Mr. Stevelly to exemplify these remarks only in the pendulum composed of a deal rod suspended by a steel spring, and a leaden tube. This pendulum is perhaps the cheapest, simplest, and best that can be made.

Let the annexed figure represent a deal rod and leaden tube pendulum; S P = 2 inches of steel spring; P D the length of the deal rod to be calculated; L D = 2 z = length of leaden tube; B a deal circular bracket, either turned and fastened upon the end of the deal rod or made out of the same solid piece of white deal wood with the rod, its use being to give a firm support to the leaden tube. Let 2 r = the outside diameter of the leaden tube, and 2 r' equal the diameter of the cylindric hole along its axis which receives the deal rod; let G be the centre of gravity, and O the centre of oscillation. Let S G = λ and S O = (for a royal seconds pendulum) 39·13929 inches: denote this by l.

It can then be easily shown by the formulæ for centre of oscillation, that

$$l = \frac{\frac{r^2 + r'^2}{4} + \frac{z^2}{3}}{\lambda} + \lambda \therefore l - \lambda = \frac{\frac{r^2 + r'^2}{4} + \frac{z^2}{3}}{\lambda} \ldots (a)$$

By applying the differential calculus to find the change of position of O for changes of temperature, we shall see that since l is constant,

$$d(l - \lambda) = -d\lambda = \frac{\frac{2rdr + 2r'dr'}{4} + \frac{2z\,dr}{3}}{\lambda} - \frac{\left(\frac{r^2 + r'^2}{4} + \frac{z}{3}\right) d\lambda.}{\lambda^2}$$

Hence

$$\div d\lambda\left(\frac{\lambda^2-\frac{r^2+r'^2}{4}-\frac{z^2}{3}}{\lambda^2}\right)=\frac{\frac{2\,r\,dr+2\,r'\,dr'}{4}+\frac{2\,z\,dz}{3}}{\lambda}$$

Hence

$$-d\lambda=d\,(l-\lambda)=\left(\frac{\frac{2\,r\,dr+2\,r'\,dr'}{4}+\frac{2z\,dz}{3}}{\lambda^2-\frac{r^2+r'^2}{4}-\frac{z^2}{3}}\right)\lambda$$

Now if we denote by dm the change of length which the unit length of the metal of which the tube is formed, suffers from the change of temperature to which the pendulum has been subjected, then $dr=r\,dm$: $dr'=r'\,dm$: and $dz=z\,dm$; and substituting these, we have

$$d\,(l-\lambda)=\left(\frac{\frac{r^2+r'^2}{2}+\frac{2\,z^2}{3}}{\lambda 2-\frac{r^2+r^2}{4}-\frac{z^2}{3}}\right)\lambda\,dm$$

The height of the point O, above the bracket which supports it is, $=z-(l-\lambda)$. Hence the change of place of O, upwards or downwards in relation to the bracket, is the differential of this, and is therefore equal to

$$\left(z-\frac{\left(\frac{r^2+r'^2}{2}+\frac{2\,z^2}{3}\right)\lambda}{\lambda^2-\frac{r^2+r'^2}{4}-\frac{z^2}{3}}\right)dm$$

Now the coefficient of dm in this expression is manifestly the length of the metallic part of the pendulum, whose changes for temperature are to compensate the changes of the suspending rod; whereas the length of that metal, according to Kater, is the height of *o* above the bracket, which is

$$z-(l-\lambda)=z-\frac{\frac{r^2+r'^2}{4}+\frac{z^2}{3}}{\lambda}$$

In other words, this is Kater's coefficient for dm; and since

$$\lambda^2-\frac{r^2+r'^2}{4}-\frac{z^2}{3}\angle\lambda^2\therefore\frac{\left(\frac{r^2+r'^2}{2}+\frac{2\,z^2}{3}\right)\lambda}{\lambda 2-\frac{r^2+r'^2}{4}-\frac{z^2}{3}}\,7\,\frac{\frac{r^2+r'^2}{4}+\frac{z^2}{3}}{\lambda}$$

Consequently, for any given z, Kater's coefficient will be greater than the true coefficient; therefore, it hence appears that he will

be led to use a less z, or a less length of metallic tube than that which will truly compensate the changes of the suspending rod.

But to proceed with the investigation,—if ds and dp respectively denote the alterations of the unit length of steel and of white deal for the same change of temperature that causes dm in the unit length of the metal used for the compensating tube, then the measures being expressed in inches we shall have

$$2\,ds + (\lambda - 2 + z)\,dp = \left(z - \frac{\left(\frac{r^2 + r'^2}{2} + \frac{2\,z^2}{3}\right)\lambda}{\lambda^2 - \frac{r^2 + r'^2}{4} - \frac{z^2}{3}} \right) dm$$

Since we have supposed the steel spring to be two inches long, and the length of the deal rod is $\lambda - 2 + z$ inches; or,

$$2\,(ds - dp) + \lambda\,dp - z\,(dm - dp) = -\,2\,\frac{\left(\frac{r^2 + r'^2}{4} + \frac{z^2}{3}\right)\lambda}{\lambda^2 - \frac{r^2 + r'^2}{4} - \frac{z^2}{3}}\,dm \ldots\ldots (b)$$

But from (a) it will appear that $\lambda^2 - \frac{r^2 + r'^2}{4} - \frac{z^2}{3} = 2\,\lambda^2 - l\,\lambda$

And solving (a) for λ, we get $\lambda = \frac{l}{2} + \sqrt{\frac{l^2}{4} - \frac{r^2 + r'^2}{4} - \frac{z^2}{3}}$.

the value of λ, found with the negative radical, being the intercept between the centre of gravity and centre of oscillation. Now if we denote by R the radical in the value of λ, and substitute these quantities in (b), we shall have

$$2(ds - dp) + \frac{l}{2}dp + \mathrm{R}\,dp - z\,(dm - dp) = -\left(\frac{\frac{r^2 + r'^2}{4} + \frac{z^2}{3}}{\mathrm{R}}\right) dm$$

or, by reducing, substituting for R^2 its value, and dividing by $dm - dp$

$$\left(\frac{2\,(ds - dp) + \frac{l}{2}dp}{dm - dp} - z\right)\mathrm{R} + \frac{z^2}{3} = -\,\frac{l^2}{4}\,\frac{dp}{dm - dp} - \frac{r^2 + r'^2}{4}$$

According to the table given by Kater, $ds = \cdot 0000063596$, $dp = \cdot 0000022685$, and if the material of the tube be lead, $dm = \cdot 0000159259$; also, $l = 39\cdot 13929$. If we assume the diameter of the leaden tube to be an inch and a half, and the hollow along its axis to be six tenths of an inch, then write $r = \cdot 75$, and $r' = \cdot 3$, and substituting these respective values in the foregoing equation, and changing the signs of all the terms, we shall have

$$(z - 3\cdot 84963)\left(382\cdot 807880426025 - \frac{z^2}{3}\right)^{\frac{1}{2}} - \frac{z^2}{3} = 63\cdot 774774 \ldots (c)$$

Now by a well-known method, it is easy to find that $z = 8 \cdot 48252$ will very nearly satisfy this equation; so nearly that the change of a unit in the fifth decimal place will make the side of the equation upon which z lies differ from the other constant side in the fourth decimal place by nearly two units. This is an accuracy quite unnecessary in practice, but Mr. Stevelly resorted to it, lest in quantities depending for their values upon such minute fractions as dp, ds, and dm, there should be any source of fallacy in the mode of calculating which did not readily appear; and this course he was the rather led to adopt as the length of z which he arrived at differs so materially from that assigned by Captain Kater, and also by Mr. Baily, if the latter be correctly quoted by Kater, in Lardner's Mechanics. Mr. Baily's paper in the Astronomical Memoirs, Mr. Stevelly had no opportunity of seeing. The length of $2z$ according to Kater should be 14·44 inches, and according to Baily, as quoted by him 14·3. Now if either of these values be assigned to $2z$; z will be far from satisfying the equation (c) which has been above deduced.

The dimensions of the several parts of the pendulum according to Mr. Stevelly will be as follows:—A steel spring two inches long, measured from the cock to the upper edge of the (iron) rivet which attaches it to the deal rod; a deal rod furnished with a circular bracket at the bottom, diameter of deal rod = 0·6 inch.; length from upper edge of the rivet above, to the upper surface of the bracket upon which the leaden tube rests, = 44·995 inches. The bracket may be easily made of such a shape, while its upper circumference is nearly equal to that of the leaden tube, as that the wooden part of the pendulum alone shall swing in a second. The leaden tube is then to be 16·965 inches long; external diameter = 1·5 inch; diameter of the space along its axis, through which the deal rod passes, six tenths of an inch: the leaden tube will weigh about ten pounds avoirdupois.

If the numbers assigned by Kater be more correct than these, it can only arise from the values of ds, dp, and dm not having been as yet ascertained with sufficient accuracy, and perhaps an examination of the rates of pendulums made of tubes and rods of various materials would furnish the best possible method of examining the relative expansibilities of bodies under various temperatures.

Mr. Stevelly thinks a bracket of wood firmly attached to the lower part of the pendulum rod a method of suspending the leaden tube much to be preferred to the method in use by a nut and screw, for many reasons; and thus mounted it becomes necessary to have, at the upper part or suspension of the pendulum, some contrivance for adjusting its length, so as to make the rate correct. Mr. Stevelly exhibited to the section a nut and screw worked by a micrometer screw, the index of which may come out at the side of the clock-case, and there point to a graduated circle; and he stated that so nice an adjustment may be effected by this, that upon a circle of about three inches in diameter, each division; being the tenth of an inch in length; would correspond to an alteration of the length of the

pendulum equal to the 140,000dth part of an inch; while the entire suspending apparatus may be firmly screwed to the stone back of the clock-case, and thus afford a very steady means of suspension, quite independent of the clockwork. By this means an alteration of the rate of the clock may be effected without stopping it; and an alteration to any required amount may be at once effected, after it has been ascertained by experiment what change is made in the rate by moving the micrometer index through a given number of the degrees of its circle.

A leaden tube, such as here described, can be very easily drawn at any place where leaden tubes are manufactured, and is the cheapest and best material for the purpose. It will be proper to prepare the deal rod by baking; then by passing it through a cork in the upper part of the receiver of an air pump, the ends of it can be dipped into melted shell lac after the air has been extracted; the readmission of the air will drive the lac into the pores; its outside surface should also be made of the colour of lead by rubbing it with black lead, a matter well known to be of considerable importance; and when the parts of the pendulum are put together, all may be varnished.

On the Importance of forming new Empirical Tables for finding the Moon's Place. By J. W. Lubbock, Esq.

During the last and the present century the tables for finding the places of the moon and planets have been so much improved that they may now be considered as sufficiently accurate for the purposes of navigation. If therefore astronomical tables were to be viewed merely with reference to the facilities which are obtained through their means for long voyages, astronomers might be said to have accomplished all that was expected from them. Astronomers, however, have never been satisfied with this view of the question, but they have constantly endeavoured to reach by calculation and theory the same degree of accuracy as that which is obtained in fixed observatories with the best instruments. This being the case much remains to be accomplished. The expressions for the longitude and latitude of the moon, to which I shall confine myself in the following remarks, have not yet arrived at the desired precision, although the difficulties which remain to be overcome are by no means insurmountable.

The most remarkable works on the theory of the moon, on account of their extent, are those of MM. Damoiseau and Plana.

M. Damoiseau's work, to which a prize was adjudged by the French Institut, was published by that learned body in the *Mémoires des Savans Etrangers*. M. Damoiseau has pushed to an almost incredible extent the approximation, following closely the method given by Laplace in the *Méc. Cel.*, and originally chosen by Clairaut. But M. Damoiseau's calculations are so conducted and are presented in such a shape, that it would be next to impossible to verify them, nor do I think that such a verification will ever be attempted.

The publication of M. Plana's work constitutes a new era in the question, from the circumstance that the results are therein developed by M. Plana according to powers of the eccentricities, inclinations, &c., and also of the quantity m, which denotes the ratio of the sun's mean motion to that of the moon. The methods employed by M. Plana are otherwise similar to those of M. Damoiseau, but M. Plana's results possess the inestimable advantage of permitting each term of which a coefficient is composed to be verified separately. The form in which M. Plana's results are presented also enables us to examine them with facility and to judge of their convergence. Unfortunately we soon find that the expressions for the coefficients in many cases do not converge, so that it will be difficult, if not impossible, to push the approximation so far as to arrive *à priori* at expressions upon which reliance can be placed for the principal inequalities, such for example as the *annual equation* in longitude*.

In consequence of this difficulty I wish to call the attention of the Section to the importance of deducing the numerical values of these coefficients from the best observations *empirically*, and of thus constructing new Lunar Tables, which may serve to check the results obtained by theory, and which may be *in form* unobjectionable. The Tables of Burckardt, otherwise of great merit, and the best empirical Tables of the Moon at present in existence, were constructed before theory had been brought to its present state; and their form is such that it would be difficult to render them available in the manner I have pointed out.

M. Plana has pushed the approximation to so great an extent that if his figures could be depended upon the subject might perhaps be considered as exhausted practically; but notwithstanding M. Plana's great skill and care, of which I am well convinced, it is unlikely that calculations of such prodigious difficulty and complexity should be free from errors.

The construction of empirical Lunar Tables such as I have recommended resolves itself into a question of expense; for we have computers in this country who are competent to undertake a work of this nature under proper guidance.

On the Action of Crystallized Surfaces upon Common and Polarized Light. By Sir David Brewster, K.G.H., V.P.R.S.Ed.

In the year 1819 I submitted to the Royal Society a series of experiments on the action of crystallized surfaces on common and polarized light. These experiments established in the clearest man-

* According to M. Plana this coefficient contains the following terms:

$$-3m+\frac{735}{16}m^3+\frac{1261}{4}m^4+\frac{142817}{96}m^5$$
$$+\frac{3257665}{576}m^6+\frac{964470235}{55296}m^7+\&c.$$

ner that the interior forces, which produce double refraction, extend within the sphere of the ordinary reflecting force, and modify its action not only in polarizing common light and changing the planes of polarized light, but in reflecting different quantities of light at different angles of incidence.

These experiments excited no attention among those who were studying the theories of light till 1835, when they attracted the notice of Mr. Maccullagh, of Trinity College, Dublin, who was then engaged in investigating the laws which regulate the reflexion and refraction of light at the separating surface of two media.

From principles analogous to those employed by Fresnel, Mr. Maccullagh has anticipated effects quite the reverse of those deduced from my experiments ; and in order to account for the latter he was obliged to abandon to a certain degree the physical ideas of Fresnel in so far as to make the vibrations of the wave *parallel* to its plane of polarization, in place of perpendicular to it. From the theory thus modified Mr. Maccullagh has shown that when a ray is polarized by reflection from a crystal the plane of polarization deviates from the plane of incidence, *except when the axis lies in the latter plane*. The formula which expresses this deviation represents very accurately the measures of the polarizing angles in different azimuths, which I have obtained in the only surface in which the exception is true ; but at all other inclinations of the reflecting plane to the axis, the formula and the theory are in fault, as there is a large deviation when the axis or principal section of the crystal is in the plane of reflexion.

After the publication of my paper of 1819 I had more than once resumed the subject ; but the difficulty of obtaining highly polished surfaces of calcareous spar at different inclinations to the axis forced me to abandon the inquiry. When I found, however, that Mr. Maccullagh had succeeded in deducing from theory the general fact of a deviation increasing as the refractive power of the medium approached to that of the spar, I had no doubt that he would bring the more complex phenomena under the dominion of theory, provided I could furnish him with their physical law. In this expectation I devoted my whole time to the inquiry during the last winter, with more knowledge of the subject and better means of observation ; and I should have made much greater progress than I have done had I been able to procure crystals of calcareous spar suited to my purpose. In this difficulty I applied to the British Museum through Mr. König, for some useless fragments of their specimens, but I was mortified to find that an Act of Parliament prohibited even the dust of a crystal from being removed from its walls.

The difficulty which I experienced in obtaining crystals with planes sufficiently regular and polished, obliged me to work with artificially polished surfaces ; and I have to express my obligations to Mr. Nicol, of Edinburgh, for the kindness and the love of science which led him to polish with his own hands the surfaces which I required.

In attempting to give the Section some idea of the nature and singularity of the results which I obtained, I shall omit all details and confine myself to the statement of the general phenomena.

When light is reflected at the separating surface of two media, the lowermost of which is a doubly refracting one, the reflected ray is exposed to the action of two forces, one of which is the ordinary reflecting force, and the other a force which emanates from the interior of the doubly refracting crystal. When the first medium is air, or even water, the first of these forces overpowers the second; and in general the effects of the one are so masked by the effects of the other that I was obliged to use oil of cassia,—a fluid of high refractive power,—in order that the interior force of the calcareous spar, which I wished to examine, might exhibit its effects independently of those which arise from ordinary reflexion. The separating surface therefore which I used had a small refractive power, and the reflecting pencil is so attenuated, especially in using polarized light, that it is almost impossible to use any other light than that of the sun.

When a pencil of common light is reflected from the separating surface of oil of cassia and calcareous spar, the general action of the spar is to polarize a part of the ray in a plane perpendicular to that of the reflexion, and thus to produce *by reflexion the very same effect that other surfaces do by refraction.*

On the face of calcareous spar perpendicular to the axis of the crystal the effect is exactly the same in all azimuths, but in every other face the effect varies in different azimuths and depends upon the inclination of the face to the axis of double refraction. On the natural face of the rhomb common light is polarized *in the plane* of reflexion in 0° of azimuth, or in the plane of the principal section; but at 38° of azimuth the whole pencil is polarized at right angles to the plane of reflexion, and in other azimuths the effect is nearly the same as I have stated in my printed paper.

In order, however, to observe the change which is actually produced upon light it is necessary to use two pencils, one polarized + 45°, and the other − 45° to the plane of incidence. The planes of polarization of these pencils are inclined 90° to each other, and the invariable effect of the *new* force is to augment that angle in the same manner as is done by a refracting surface, while the tendency of the ordinary reflective force is to diminish the same angle. Hence I was led to make an experiment in which these opposite forces might compensate one another. I mixed oil of olives and oil of cassia till I obtained a compound of such a refractive power that its action in bringing together the planes of polarization should be equal to the action of the new force in separating them. Upon reflecting the compound pencil from this surface I was delighted to find that the inclination of the planes was still 90°, and I thus obtained the extraordinary result of a reflecting surface which possessed no action whatever upon common or upon polarized light.

The action of the new force when the plane of reflexion coincides with the principal section of the crystal is obviously inexplicable by

any theory of light, though I have no doubt that the undulatory theory will ultimately accommodate itself to this as well as to other classes of phenomena which it does not at present embrace. The difficulty, however, is increased by another result of my experiments which it is important to notice. On the faces of the spar which are inclined 0°, 45°, and 90° to the axis of double refraction, the action of the new force is symmetrical upon the two pencils of polarized light, whose planes are inclined + 45°, and − 45° to the plane of incidence, whereas in all intermediate faces whose inclination to the axis is $22\frac{1}{2}°$ and $67\frac{1}{2}°$, the plane of one of the polarized rays remains stationary, while that of the other is turned round 15°.

This effect is undoubtedly a very extraordinary one, and indicates some singular structure in calcareous spar, the nature of which it is not easy to conjecture.

I have examined these phenomena by using in place of oil of cassia various fluids whose refractive powers descend gradually to that of water; but it would be a waste of time to give any detailed account of them at present. I shall only state that the action of the new force becomes weaker and weaker as the force of ordinary reflexion is increased by diminishing the refractive power of the oil which is placed in contact with the spar. With an oil of the highest refractive index the action of the new force predominates over the feeble power of the ordinary force of reflexion. With an oil of a lower index the two forces exactly balance each other, while with oils of still lower indices of refraction the ordinary force overcomes and conceals the action of the new one.

Although I have obtained pretty accurate measures of the amount of the deviations produced by the new force on eight surfaces differently inclined to the axis, and in various azimuths on these surfaces, yet many experiments are still necessary before we can hope to discover the physical law of the phenomena; and if this should be done I have no doubt that Mr. Maccullagh will be equally successful in the higher attempt of accounting for them by some modification of the undulatory theory.

On a singular Development of Polarizing Structure in the Crystalline Lens after Death. By Sir David Brewster, K.G.H., V.P.R.S.Ed.

In examining the changes which are produced by age in the polarizing structure of the crystalline lenses of animals, I was induced to compare these changes with those which I conceived might take place, after death, when the lens was allowed to indurate in the air, or was preserved in a fluid medium. After many fruitless experiments I found that distilled water was the only fluid which did not affect the transparency of the capsule, and my observations were therefore made with lenses immersed in that fluid. The general polarizing structure of the crystalline in the *sheep*, *horse*, and *cow*, consists of *three* rings, each composed of *four* sectors of polarized

light, the two innermost rings being *positive* like *zircon*, and the outermost *negative*, like *calcareous* spar. In other cases, especially when the lenses were taken from older animals, *four* rings were seen, the innermost of which was positive as before,and the rest *negative* and *positive* in succession.

I now placed a lens which gave three rings, in a glass trough containing distilled water, and I observed the changes which it experienced from day to day. These changes were such as I had not anicipated; but though I have observed and delineated them under various modifications, I shall confine myself at present to the statement of the general result. There is a *black* ring between the two positive structures or luminous rings. After some hours' immersion in distilled water, this black ring becomes *brownish*, and on the second day after the death of the animal, a *faint blue* ring of the first order makes its appearance in the middle of it, and its double refraction, as exhibited by its polarized tint, increases from day to day, till the tint reaches the *white* of the first order. Simultaneously with this change of colour, the breadth of this new ring gradually increases, encroaching slightly upon the inner positive ring, but considerably upon the *second* positive ring; so that the black or neutral ring which separates the two positive structures, and in the middle of which a new luminous ring is created, divides itself into two black neutral rings, the *one* advancing *outwards*, and *diminishing* the breadth as well as the intensity of the second series of positive sectors, and the other advancing inwards, and diminishing the breadth and intensity of the inner or central sectors. While these changes are going on, the *outer* luminous or *negative* ring advances inwards, encroaching also on the *second* positive ring.

Upon examining the character of the new luminous ring, the development of which has produced all these changes, I found it to be *negative*, so that at a certain stage of these variations we have a *positive* and a *negative* doubly refracting structure succeeding each other alternately, from the centre to the circumference of the lens, such as I have often observed in lenses taken from animals of greater age, and examined immediately after death.

After this stage of perfect development, when there is a marked symmetry both in the relative size and polarizing intensities of the four series of sectors, the lens begins to break up. The new *negative* ring encroaches so much on the two *positive* ones, which it separates, that the outer one is sometimes completely extinguished, while the breadth and tint of the inner sectors are greatly diminished, so that the highest double refraction exists in the newly developed ring. In a day or two this ring also experiences a great change of distinctness and intensity, and the lens commonly bursts on the fifth or sixth day, sometimes in the direction of the septa or lines where its fibres have their origin and termination, and sometimes in other directions.

In order to give a general idea of the cause of these singular changes, I may state that the capsule which incloses the lens is a highly elastic membrane—that it absorbs distilled water abundantly

—and that, in consequence of this property, the lens gradually increases in bulk, and becomes more globular, till the capsule bursts with the expansive force of the overgrown lens. That the reaction of the elastic capsule contributes to modify the polarizing structure of the interior mass, cannot admit of a doubt, as it is easy to prove that that structure is altered by mechanical pressure; but I cannot conceive how such a reaction could create a new negative structure between two positive ones, and produce the other phænomena which I have described. I have been led therefore to the opinion, that there is in the crystalline lens the germ of the perfect structure, or rather the capability of its being developed by the absorption of the aqueous humour; that this perfect structure is not produced till the animal frame is completely formed; and that when it begins to decay the lens changes its density and its focal length, and sometimes degenerates into that state which is characterized by hard and soft cataract.

The results of which I have now given an exceedingly brief notice, appear to me to afford a satisfactory explanation of those changes in the lens which terminate in cataract, a disease which seems to be more prevalent than in former times. Accidental circumstances have led me to study the progress of this disease in one peculiar case, in which it was arrested and cured; and I am sanguine in the hope that a rational method of preventing, and even of stopping the progress of this alarming disease, before the laminæ of the lens have been greatly separated or decomposed, may be deduced from the preceding observations.

As the experiments, however, and views upon which this expectation is founded, are more of a physiological than of a physical nature, I am desirous of submitting an account of them to the Medical Section, that they may undergo that strict examination which they could receive only from the experience and science of that distinguished body.

On the Laws of Double Refraction in Quartz. By J. M'CULLAGH, *Fellow of Trinity College, Dublin.*

Among the *desiderata* of optical science, one of the most remarkable is a mechanical theory of the laws of double refraction in quartz, or rock-crystal. These laws, which, as far as we know, are peculiar to that crystal, were made out by the successive labours of Arago, Biot, Fresnel, and Airy; of whose researches a full account has been given in the Report on Physical Optics, drawn up for the Association by Professor Lloyd*. But the laws so discovered were merely isolated facts; no connexion had been traced amongst them, if we except Fresnel's beautiful explanation of the rotatory phænomena. It was the object of Mr. M'Cullagh's communication to

* *Reports of the British Association for the Advancement of Science,* vol. iii. p. 405—409.

prepare the way for a mechanical theory, by showing that all the phænomena may be grouped together by means of a simple geometrical hypothesis, which consists in the addition of certain terms (involving only one new constant,) to the ordinary differential equations of vibratory motion. The ordinary equations contain two second differential coefficients of the displacements—one with respect to the time, the other with respect to the coordinate z, perpendicular to the wave. The additional terms may be any odd differential coefficients (with respect to z) of the alternate displacements, these coefficients being multiplied by a proper function of the length of a wave. The third differential coefficients are chosen for simplicity, because then the multiplier is a constant quantity. Setting out from this hypothesis, we arrive immediately at all the known laws, and obtain at the same time a law that was previously unknown, and which is technically called the *law of ellipticity*. This law is extremely simple, being expressed by a quadratic equation. Two sets of experiments, made long ago by different observers, and relative to two classes of phenomena, between which no connexion was hitherto perceived, are now, by the law of ellipticity, connected in such a way, that the one may be computed solely from the data furnished by the other; the ellipticities observed by Mr. Airy in rays inclined to the axis of quartz, being computed from the angles of rotation observed by M. Biot in rays parallel to that axis, and a strict agreement being found between calculation and experiment. The discontinuous form of the wave-surface in quartz is also explained, and its equation for the first time determined. The particulars of the investigation will be published in Vol. XVII. of the *Transactions of the Royal Irish Academy*.

On Polarization. By the Rev. Edward Craig.

The Rev. Mr. Craig read a paper to show that the phænomena of polarization are consequences and indications of the molecular structure of refracting substances, and explicable by it; illustrating his views by some uniaxal crystals, and particularly the Iceland spar.

On some Phænomena of Electrical Repulsion. By Wm. Snow Harris, *F.R.S.*

The only connected and extensive series of experiments in statical electricity which have ever appeared are those of Coulombe, communicated to the Royal Academy of Sciences at Paris so long since as the years 1782 and 1789; since which time, if we except the valuable contributions of Professor Robison of Edinburgh, little has been effected in this department of science. Coulombe's highly important researches, however, altogether rest upon the principle of electrical repulsion, employed as a quantitative measure, through the agency of the proof plane and the torsion balance. The author therefore considers, that some further verification of the experimental processes resorted to by this distinguished philosopher is still a

desideratum in common electricity, more especially as it may be shown that the divergence of similarly electrified bodies is, in its application to quantitative processes, liable to much discrepancy.

The author exhibited his new species of balance, some account of which he had already submitted to the Physical Section at the last Meeting of the Association; since this however it had undergone considerable revision. The reactive force of this instrument, termed a biple balance from the peculiar principle of its action, is not derived from elasticity as in the balance of torsion of Coulombe, but is altogether dependent on gravity; it seems extremely well adapted to the measurement of small forces generally, and to researches in electricity and magnetism, and may be converted if required into a balance of torsion, free from many difficulties of a mechanical kind, generally attendant on the employment of that instrument.

In examining the operation of the repulsive force between two small insulated discs of ·4 of an inch in diameter, the author finds that the repulsion is not always in the ratio of the quantity of electricity with which either, or both the discs is charged; or as the squares of the distances inversely, according to the general expression $\frac{F}{D^2}$ deducible from Coulombe's researches. That hence the two constants $R\,R'$ of which we may suppose the force F to be made up, do not necessarily enter into the composition of the result, so as to cause the total force to increase or diminish with the electricity contained in either. The author here referred to the tabulated results of above five hundred experiments, taken in a good insulating atmosphere. In these experiments the discs were both equally and unequally charged with electricity in known proportions, and placed at various distances apart. From these results it appeared,

First, that the forces were only as the squares of the distances inversely when the repelling bodies were equally charged, and to a moderately high intensity, and even then this law did not always obtain at all distances; when the discs began to closely approximate the law was observed to vary, and at last to approach that of the inverse simple distance.

Second, the deviations from the general law deducible from Coulombe's experiments are more apparent as the intensity of the charge is diminished, the inequality of the respective quantities with which each body is charged greater, and the distance less; under any or all of these conditions, the rate of increase of the repulsive force diminishes, and the repulsion is at length superseded by attraction.

Third, the quantity of electricity contained in either of the repelling bodies is not always in the ratio of the repulsive forces: thus it was seen by the tabulated results, that the respective quantities of electricity at a constant distance D were in several instances in the ratio of 2 : 1 and 4 : 1, whilst the corresponding forces of repulsion were as 3 : 1 and 5 : 1 respectively. Hence the electrical reactions may be in one proportion, and the quantities of electricity in another.

Although these results may seem at first anomalous, yet they are still such as would necessarily arise out of the known operation of electrical induction. The inductive process is not confined to the case of a charged and neutral body, but operates more or less freely even between bodies similarly charged: whatever therefore be the precise nature of the inductive force, it is present in every case of statical electrical action, although under certain conditions the resulting attraction attendant on it is not always apparent, or is otherwise of a negative character; the tendency of the inductive action being first, to raise the anti-attractive state of the bodies to zero, if such previously exist; secondly, to generate in them an actual attractive force. He conceives, therefore, that no essential difference exists in this process, whether it take place between similarly or dissimilarly charged bodies, or between a charged and a neutral body. The only distinction necessary is, that in the latter case the induction commences at a limit which may be termed zero; in the former cases it commences either above or under that limit. The author considers that electrical induction between two similarly charged bodies, may become indefinitely modified by the various circumstances of quantity, intensity, distance of the repelling bodies, and the like, giving rise to apparently complicated phenomena, as he thinks is evident in his tabulated results. One condition favourable to the disturbances above mentioned, and of importance to notice, is the inequality of the repelling bodies in respect of extension. Thus in connecting an insulated sphere with the fixed ball of the balance, the force between the discs will be often in the simple inverse ratio of the distance, or at least very nearly in that ratio, and will be frequently in the ratio of 3 : 1, when the quantity of electricity on the charged sphere is as 2 : 1.

The author considers these facts of great consequence to any experimental inquiry in electricity through the agency of repulsion, more especially those connected with the use of the proof plane. The relative electrical capacities of a hollow sphere and a circular plate of equal area, each side to each side, as determined by Coulombe's method, is involved in some uncertainty on this account. In the detail of Coulombe's experiments, given in Biot's celebrated *Traité de Physique*, the capacities of the plane and sphere appear to be in the ratio of 2 : 1. Hence the plane is considered to have a double surface of action, the interior surface of the sphere not participating in the distribution of the charge. The result of the contact however of the plane and sphere, and from which it is inferred that the electricity became finally shared between them, in proportion to their exterior surfaces, does not seem to have been compared with the result of a similar contact between the charged sphere and a neutral sphere of the same diameter. According to the theory, the electrical reactions after contact with the plate should greatly exceed that after contact with a similar sphere; it should in fact be the same as that after contact with a sphere whose exterior surface was equal to the two surfaces of the plate. This point deserves

great attention since it is of importance to an exact theory of electricity.

The author submitted to experiment under various conditions, two equal spheres and a circular plate of the same extent of surface, each side to each side, and found their electrical capacities precisely the same. Thus the result of the contact with the charged sphere and a similar neutral sphere, or with a circular neutral plate, was precisely the same. The same quantity of electricity disposed either upon the sphere or plate, in connexion with the fixed ball of the balance, evinced the same intensity; and this intensity became also equally diminished, whilst thus connected, whether the charged body was touched with a sphere or circular plane of the same area. The author does not pretend to question the faithfulness of Coulombe's experiment, but considers his result embarrassed by the circumstances just mentioned; more especially as he found, that when the electricity was equally distributed upon the repelling discs of the balance, and the square roots of the forces taken to determine the respective quantities of electricity, then the apparent differences in the capacities of the sphere and plate vanished; he considers therefore that the traces of repulsion indicated by the balance did not in Coulombe's experiment truly represent the ratio of the quantities of electricity before and after the contact between the sphere and plate.

These results were further verified by means of the attractive forces, through the agency of a new electrometer, and which the author exhibited and explained to the Physical Section at a former meeting of the Association. The author next proceeded to consider more at large the operation of the proof plane, and presented to the Section the results of numerous experiments on tangent planes of various degrees of thickness and extension, from which it appeared that the indications of the proof plate might be so materially influenced by the circumstances of position, intensity of the charge, thickness, and the like, as not always to become charged, either with a similar quantity or in the ratio of the quantity of electricity with the point of the electrified body to which it is applied. In treating of the proof plane, philosophers have considered its action in more than one point of view. Mons. Biot states that it takes up upon each of its surfaces as much electricity as exists upon the point touched, hence on removal it is charged with twice the quantity of electricity as that of the corresponding superficial element. Mons. Pouillet, on the contrary, considers the proof plane to be in precisely the same state as the superficial element itself, and to be on removal in the same condition as a similar portion of the charged body would be, if actually taken out of its surface, that is to say, the electricity would be first collected on one surface, and be subsequently expanded on both; each surface has therefore only half the quantity of the superficial element, and the proof plane comes away charged with the same quantity, but under a diminished intensity. The author deems it worthy of further inquiry, whether the proof plane be really identical with an element of the charged surface, or whether it be merely

in the condition of a neutral insulated body of small capacity, placed within an extremely small distance of a charged body; and subject to the same laws as subsist between two such bodies under ordinary circumstances at more considerable distances, but at which a communication of electricity can take place, a rigorous examination of this question would probably elucidate many phenomena of electrical action, at present involved in some obscurity. In the meantime he thinks it not unimportant to review such facts connected with this point as are already known. It has been found, for example, that the attractive force between charged and neutral bodies is less when the neutral bodies are insulated, that very perfect insulators are not sensibly attracted by electrified substances, and that in every case of electrical attraction the force is only in proportion to the previous induction of which the bodies are susceptible; in accordance with these facts, a perfectly insulating disc reposes on a charged surface without becoming sensibly electrified, an insulated neutral conducting disc more or less so in proportion to its thickness, whilst a similar disc, whose inductive susceptibility is rendered nearly perfect by artificial methods, becomes charged with an intensity nearly equal to that of the point to which it is applied. Should therefore the inductive susceptibility of the tangent disc be so influenced by position, in respect of the electrical molecules of the charged body, as to become at any time nothing; it would be as inefficient in abstracting electricity, as a similar disc of any nonconducting substance. Now it is not improbable that an insulated conducting body of small dimensions, plunged within a spherical charged shell, is thus circumstanced; and hence it fails to become in any degree charged, notwithstanding that electricity may, experimentally, be clearly proved to exist there.

From these and a variety of other considerations, the author is disposed to believe, that the force communicated to a proof plane cannot always be considered as a faithful indication of the electrical state of a charged surface, since it forms no integral part of that surface, being really placed under the conditions of an insulated neutral body of small and variable capacity, arising from the circumstances of position, thickness, and the like, and which is about to receive electricity from a charged body. He thinks that we really know little about the actual distribution of electricity upon a charged surface, except through the medium of insulated discs, in some way applied to it. Now he has already shown* that any charged body only gives off its electricity under the influence of an attractive force; so that an electrified sphere, when completely insulated, will retain its charge in the best vacuum which can be obtained by ordinary means, provided it be free from any sensible source of attraction. It is not therefore until we employ some substance susceptible of induction, that we begin to disturb the electrical distribution in charged bodies, which may be previously uniform or nearly so.

In conclusion, the author observed, that our present theories of electricity may probably be found to require some considerable mo-

* *Phil. Trans.* for 1834, p. 242.

dification, and thought the subject highly worthy of the learning and ability so conspicuously displayed by the English mathematicians. He did not consider the ordinary theory of electrical distribution, or the experimental data on which it depended to be so completely free from objection, as to render all doubts of its accuracy unpardonable; he thinks that the attractive forces between charged and neutral bodies in a free state depend only on the surfaces immediately opposed, without regard to any hypothetical distribution arising from the peculiar form or disposition of the unopposed parts; he has calculated from very simple elements, the force which should arise between opposed planes and spheres, and bodies of various forms, whether connected or not with other masses, without any reference whatever to the distribution of the charge, and finds the result verified by experiment.

A Series of Experiments in Electro-magnetism, with Reference to its Application as a Moving Power. By the Rev. J. W. M'Gauley.

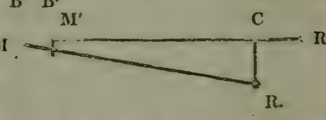
Mr. M'Gauley thought it might not be inappropriate to mention to the Section what he had done in the application of electro-magnetism to machinery since the last meeting of the British Association. He would mention the principal difficulties which remained to be overcome, after the construction of the working model he had exhibited at Dublin. These, he believed, he *had* overcome, and had in his possession a machine of not inconsiderable power.

1st. Powerful magnets were to be constructed: the ordinary ones were very imperfect, and their effect limited to inconsiderable distances; their size could not be very great, as the helix must be proportioned to the iron, to saturate it, and yet cannot extend beyond a certain distance from it, or it will be inefficient, perhaps of injurious effect. A number of coiled bars cannot be united so as to form one great magnet: their poles could not be reversed, they would act on each other in a greater or less degree by induction.

2ndly. The *action* of several magnets cannot easily be united, since all the poles cannot be reversed at the same time precisely.

3rdly. If we succeed in uniting their action, that action is not easily applied to machinery: for let B be a bar of iron traversing between the magnets M and M'.

Fig. 1.



Let B be the position of the bar when C R is the position of the crank, B' its position when the crank is at C R', a dead point: if the bar is not ready to leave the magnet M', the inertia of the machinery carries on the crank, and the engine is broken, or the bar torn off, which very often deranges the reversion of the poles, nor can the mechanism applied in other cases to prevent this injurious effect, be here adopted.

Mr. M'Gauley exhibited a reversing apparatus, different from that noticed last year, in which mercury is not required, and the difficulty

of attaching it to the machinery, so as to be worked by it, is overcome. He reserved for a future occasion its description.

The following experiments he had tried with great care, securing, as far as possible, by cleaning the battery, renewing the charge, &c., a perfect identity of circumstances, without which a fair comparison could not be made.

THE HELIX.

Magnet, No. 1.—Horse-shoe soft iron bar, $13\frac{1}{2}$ inches across the poles; $5\frac{1}{4}$ interior, $7\frac{3}{4}$ exterior length; diameter of the bar $2\frac{1}{2}$ inches; keeper $13\frac{1}{2}$ inches long, $2\frac{1}{2}$ and $\frac{5}{8}$ thick. This keeper used in all experiments with magnets of the same size. The magnet covered with sealing-wax varnish before it was coiled like the others used in these experiments. It was coiled with 1690 feet of No. 13 copper wire, in 10 equal helices. The battery 1 foot square; double cell charged with 1 in 50 sulphuric, 1 in 100 nitric acid; lifted at distance of $\frac{3}{10}$ inch, $4\frac{1}{4}$ lbs.

——— $\frac{3}{20}$ —— $9\frac{1}{4}$ —

Removed one of the coils, and used similar charge, it lifted at $\frac{3}{10}$ inch, $7\frac{1}{2}$ lbs.

$\frac{3}{20}$ —— 37 —

Used thicker wires at the poles of magnet and batteries, at $\frac{3}{10}$ inch, $14\frac{1}{4}$ lbs.

$\frac{3}{20}$ —— 42 —

Same magnet, charge, &c. one coil of same wire, 150 feet effect at $\frac{1}{8}$ perceptible, lifted in contact $12\frac{1}{4}$ lbs.

Same magnet, &c., two coils, 300 feet, lifted at $\frac{1}{16}$ .. $5\frac{3}{4}$ lbs.

Same magnet, &c., three coils, 450 feet, lifted at

$\frac{3}{8}$ inch, $2\frac{1}{4}$ lbs.
$\frac{1}{4}$ .... $3\frac{1}{4}$
$\frac{1}{8}$ .... $4\frac{1}{2}$
$\frac{1}{16}$ .... $9\frac{1}{4}$

Same magnet, &c., four coils, 600 feet, at

$\frac{3}{8}$ inch, $2\frac{1}{2}$ lbs.
$\frac{1}{4}$ .... $3\frac{1}{4}$
$\frac{1}{8}$ .... $3\frac{3}{4}$
$\frac{1}{16}$ .... $12\frac{1}{4}$

Same magnet, &c., five coils, 750 feet,

$\frac{1}{2}$ inch, perceptible
$\frac{3}{8}$ .... $3\frac{1}{4}$
$\frac{1}{4}$ .... $2\frac{1}{4}$
$\frac{1}{8}$ .... $4\frac{1}{4}$
$\frac{1}{16}$ .... $12\frac{1}{4}$

Same magnet, six coils, 900 ft.

$\frac{1}{2}$ inch, $3\frac{3}{4}$ lbs.
$\frac{3}{8}$ 3
$\frac{1}{4}$ 3
$\frac{1}{8}$ .... $7\frac{1}{4}$
$\frac{1}{16}$ .... $18\frac{1}{4}$

Same magnet, &c., seven coils, 1050 feet,

$\frac{1}{2}$ .... } barely
$\frac{3}{8}$ .... } perceptible.
$\frac{1}{4}$ .... $2\frac{1}{4}$
$\frac{1}{8}$ .... $5\frac{3}{4}$
$\frac{1}{16}$ .... $19\frac{1}{4}$

Same magnet, &c., eight coils, 1200 feet,

$\frac{1}{2}$ inch, $7\frac{3}{4}$ lbs.
$\frac{3}{8}$ .... $9\frac{3}{4}$
$\frac{1}{4}$ .... $4\frac{1}{4}$
$\frac{1}{8}$ .... $8\frac{3}{4}$
$\frac{1}{16}$ .... $30\frac{1}{4}$

Same magnet, &c., nine coils, 1350 feet, at

$\frac{1}{2}$ inch, $5\frac{1}{4}$ lbs.
$\frac{3}{8}$ .... $6\frac{1}{4}$
$\frac{1}{4}$ .... $9\frac{1}{2}$
$\frac{1}{8}$ .... $8\frac{1}{4}$
$\frac{1}{16}$ .... $21\frac{1}{4}$

Same magnet, batteries, &c., all the coils remaining on the bar; average of a number of experiments:

	lbs.		lbs.
1 of the coils connected with battery	$2\frac{1}{4}$	2 helices forming one,	$5\frac{3}{4}$
2	$3\frac{1}{4}$	3	$4\frac{1}{4}$
3	$7\frac{1}{4}$	4	$7\frac{1}{4}$
4	$11\frac{1}{4}$	5	$6\frac{1}{4}$
5	$13\frac{1}{2}$	6	0
6	$18\frac{3}{4}$	1	$4\frac{3}{4}$
7	$22\frac{3}{4}$		
8	$26\frac{3}{4}$		
9	$19\frac{1}{4}$		

Second Series.

No. 1.—Horse-shoe iron bar, $9\frac{5}{8}$ inches long, $1\frac{5}{8}$ diameter, surmounted at poles by ground discs, 4 inches diameter, $\frac{1}{8}$ thick. Keeper, 9 long, $4\frac{3}{16}$ wide, and $\frac{3}{4}$ thick, coiled with 500 feet No. 15 iron wire, in five equal helices; charge, 1 in 50 sulphuric, 1 in 100 nitric acid:

at $\frac{1}{16}$ inch, it lifted 6 lbs.

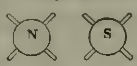
Magnet, No. 2.—Same size, coiled with 500 feet No. 13 copper wire in 5 coils; same charge &c.:

at $\frac{1}{8}$ inch, it lifted 4 lbs.
$\frac{1}{16}$ .... $7\frac{1}{2}$

Magnet, No. 3.—Same size, coiled with 500 feet No. 12 iron wire,

at $\frac{1}{8}$ inch, it lifted $1\frac{1}{2}$ lbs.
$\frac{1}{16}$ 4

Fig. 2.



Magnet. No. 4.—Same size, but discs or poles replaced by pins, retaining the coils on the bar 500 feet No. 12 iron wire. Same battery, &c. Hardly any effect.

Third Series.

In the other series, the charge is changed before every experiment. In this, the same charge is retained throughout.

Magnet, No. 1.—Soft iron square horse-shoe bar, $7\frac{3}{4}$ long, $\frac{1}{2}$ square, coiled with 90 feet No. 13 copper wire.

Magnet, No. 2.—Cast iron, same size and helix.

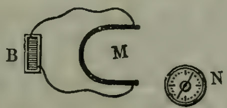
Magnet, No. 3.—Same size, but round bar diameter $\frac{5}{8}$, coiled with 90 feet of same wire, in two lengths each, distributed over the whole bar.

Magnet, No. 4.—Same size and coiled with 60 feet, in two helices; one on each half of bar; number of coils increasing from centre to poles; charge 1 in 50 sulp., 1 in 100 muriatic acid; keeper, $5\frac{3}{4}$ inches long, $\frac{7}{8}$ wide, $\frac{1}{2}$ thick.

		lbs.	oz.
Magnet, No.	1 lifted in contact	25	3½
	2	8	11½
	3	39	3½
	4	39	3

Fourth Series.

To test the comparative excellence of different charges, the galvanometer used on this occasion, was M, a small but good magnet; N, a



needle, at zero, where the magnet was connected with battery B, two inches square.

The first deflection was carefully noted; the number of degrees at which the needle settled down, and the deflection after every quarter of an hour for six quarters.

Rain water was used; sulphuric acid, specific gravity 1840; nit., spec. grav. 1410; muriatic, spec. grav. 1175; solution of caustic potash, saturated.

	1st. Def.	Settled def.	1st. Quarter.	2nd.	3rd.	4th.	5th.	6th.
Rain-water and nitric acid...... 1 in 21 parts	90°	52°	32¼	16¼	11½	4¾	3¾	3
31	38	27¾	15½	13	6½	5½	3½	2½
41	46	40	31	14½	8½	3½	2½	¾
51	38	34	26½	12¾	7½	5	3	½
Rain-water and sulphuric acid, 1 in 21	88	44	15¼	13½	9½	8½	8½	7
31	49	30¼	10	7¼	6¼	5	4	3½
41	67	44	15	8¾	5½	4½	4	2½
51	33½	24	3½	2½	2	0	0	0
Rain-water and muriat., ... 1 in 41	97	33½	7½	6¼	3	0	0	0
——————— ...... 1 in 51	58	22½	9	6½	0	0	0	0
Solution caustic potash	80	19	7¾	7	5½	4½	2¼	1¾
Sulp. 1 in 41½, nit. .... 1 in 83	98	48	24	11	7¼	6	5½	4¾
—— 1 in 26½, — .... 1 in 53	82	60	24	15½	9½	7½	6½	5½
—— 1 in 161½, — ....1 in 323	23¼	20½	7¼	4	1¾	½	0	0
—— 1 in 201½, — ....1 in 403	50	23	2½	0	0	0	0	0
Muriat. 1 in 52; sulp. .... 1 in 52	35	25	7½	6½	5¼	4½	4½	3¾
——— 1 in 52; nit. .... 1 in 52	115	62½	28½	18½	15½	10	0	0
——— 1 in 52½; sulp. ...... 1 in 103	85	46½	10	6	3½	0	0	0
Solution caustic potash and sulp. 1 in 51	88	45	8¼	6¾	4	0	0	0
——————— and nit. 1 in 51	43	0	0	0	0	0	0	0
——————— and mur. 1 in 51	25	18	0	0	0	0	0	0
Sea water from Dublin bay	½	0	0	0	0	0	0	0
——————— and sulp. 1 in 51	35	26	13	8	5¾	3¼	0	0
——————— and nit. 1 in 51	95	55	33½	15½	9½	0	0	0
Sulp., nit., and muriat., each 1 in 53	95	59	40	16	10	3	0	0

Mr. M'Gauley wished to satisfy himself by experiment, that the inverse ratio of the square of the distance is the law of the decrease of magnetic attraction, but relinquished the idea for the present, when he found that the same magnet would, with one keeper, lift one quantity at $\frac{1}{16}$ inch, with another the same quantity at 12 times the distances, both keepers seemingly appropriate.

In speaking of the nature of electro-magnetism, and its perfect identity with electricity, he remarked, that we should if possible, in comparing any agent with electricity, discover some property of the latter, not the measure of, nor dependent on either its intensity or quantity, which may be so various.

He attempted to show that the spark and shock obtained from an electro-magnet, and which indeed may be obtained from a mere heap of wire, are not the spark and shock either of the battery or the magnet; that currents cannot circulate perpetually round a magnet, as the magnetism of a bar included in an helix, so far from increasing the effect of an helix, as it should by its current, may even be made totally to prevent it, and ought to do so if it be mere induced electricity, a supposition strengthened by the otherwise universal law of electrical induction.

He mentioned that he never was able to believe that the effect of a galvanic circle was the transmission of electricity from zinc to copper in any way, and back along a wire from copper to zinc, since the force which drove it through the fluid, an imperfect conductor, ought to prevent its return; and that he had frequently tried in vain with several pairs of plates, arranged *singly* in galvanic order in waterproof cells, separated by glass plates, to deflect a needle. He believed it was the *arrangement* of particles, impossible in insulating substances, and not the *transmission*, which constituted galvanic excitement. This supposition of electricity being mere inductive arrangement of particles, he believed would unite and explain many different effects; amongst others, the agitation of the muscles of a frog, on breaking connection with a single galvanic circle; the danger of discharges passing from cloud to cloud, and the shock obtained from a heap of wire connected with a galvanic battery of a single circle.

On a New Compass Bar, with Illustrations, by means of a recent Instrument, of the Susceptibility of Iron for the Magnetic Condition. By the Rev. W. Scoresby, B.D. F.R.S., *Corresponding Member of the Institute of France, &c.*

Mr. Scoresby first exhibited to the Section a recent instrument named a *magnetometer*, invented by himself in the year 1819–20, for measuring minute magnetic attractions, and for finding the dip of the needle by the observation of the plane of no-attraction. This instrument has its principal recommendation in securing *unity of character* in experiments on the magnetic condition, by enabling the experimentalist to try and compare the energy of magnetic bars or

needles by the deviations of a compass attached to the instrument, under perfectly analogous circumstances, as to the distance and relative position of the bars and the compass.

By means of this instrument, the extreme susceptibility of *soft iron* for the magnetic condition, in the small measure of permanency belonging to that substance, was exhibited in the case of a cylindrical bar of almost six inches in length and a quarter of an inch in diameter. This bar being laid in a groove of the moveable limb of the magnetometer, and adjusted in the plane of the magnetic equator, was shown to be entirely devoid of action upon the compass needle, only $1\frac{1}{4}$ inch distance; the bar was then cautiously removed, and, whilst held in a vertical position, was merely rubbed down two or three times by the naked hand, and then replaced as before on the instrument, when it was now found, very much in accordance with former experiments, to have acquired magnetism to the extent of producing a deviation of 5° on the needle of the contiguous compass.

The object of this experiment was to point out the extreme caution which is requisite to be observed in the mere moving or handling of the substances made use of in delicate magnetical investigations, such as the needles employed in experiments on the magnetizing influence of the solar rays, since, as was now shown, the slightest concussion, or even the friction of the fingers on a bar of iron or soft steel favourably situated, may be productive of such striking effects.

Mr. Scoresby's new magnetical instrument, a *compound compass needle* or bar, was then exhibited to the Section, and its construction, adjustments, and capabilities, as far as had hitherto been ascertained, were described. The bar, which was sixteen inches in length, consisted of six equal and similar plates or ribs of tempered steel, placed parallel to each other, but not in contact; which ribs, in this case, were composed of the ordinary steel busks of the shops. It was suspended on a point of steel, and its weight partly borne, in any required proportion of the whole weight, by a single horsehair (the torsion of which within the limited range of the vibrations of the bar was insensible), suspended from a spring fixed on a cross bar, supported on pillars, and adjusted in an exact vertical position above the centre of suspension. The magnetic position was indicated by a graduated arch in the top of the instrument, with a vernier attached to each end of the bar. The principle from which this bar was considered to have its superiority over a single bar of the same weight and magnitude, was stated to be, that several thin bars of tempered steel *(tempered throughout the mass)* are found to have a greater capacity for permanent magnetism than what is afforded by the mere proportional of their mass similarly tempered, so that the six tempered bars were capable of receiving a degree of magnetic energy considerably greater than it was believed could be permanently induced in any single bar of equivalent mass, whatever might be its condition as to temper.

The author of this communication also mentioned some experiments illustrative of the general advantage of *temper* in bars or needles in a moderate degree of hardness throughout their length, instead of being tempered, as they usually are, both in sea compasses and in ordinary magnets, only at the ends. This result, which at first sight might seem at variance with those obtained by Captain Kater in his laborious investigations for determining the best construction for sea compasses, the author showed was not inconsistent with established principles; for whilst he admitted the correctness of Captain Kater's conclusion as to the superiority, in point of *original* energy, in needles tempered only at the ends, he suggested that the ultimate advantage in long voyages, where *great permanency* is requisite, or under circumstances where the permanency of the energy is much tried, would probably be found in favour of tempered needles. At all events, in regard to *compound* needles and *compound* magnets, the author had abundant experimental evidence to prove that *a thorough tempering* is absolutely necessary for the adequate retention of the advantage gained by the combination of bars over single bars of equivalent mass.

Experiments on Terrestrial Magnetic Intensity, especially in relation to the Influence of Height. By Professor FORBES.

These experiments were made with Hansteen's apparatus, the property of the Royal Society of Edinburgh, chiefly in the years 1832 and 1835. The author particularly proposed to himself the problem of the influence of height upon intensity, considering the observations of Kupffer to be quite inconclusive as well as those of preceding experimenters. He showed that by choosing stations at considerable elevations, and placed on a ridge so as to have comparatively low stations on either hand, the influence of geographical position in affecting the results may be eliminated; the intensity at the lower level for a point vertically below the elevated station being obtained by interpolation, the difference between it and the observed intensity may be fairly attributed to the influence of height abstracting from local disturbing causes. To correct for these, and likewise to attain considerable numerical exactness, multiplicity of observations is most desirable, nor can any satisfactory result be looked for from a single experiment. It appeared from the tables of Professor Forbes's observations in the Alps and Pyrenees, that the sum of the heights to which the Hansteen apparatus has been carried by him, and which forms the basis of his induction, is more than 160,000 feet, or 30 vertical miles.

The author stated that he had not yet submitted his observations to one system of calculation from which to deduce the elements of disturbance with the greatest accuracy; but he pointed out from a great number of individual observations that had the diminution due

to height amounted to anything like that assigned by M. Kupffer, it could not have failed to be at once sensible. As it was, until those calculations were made he did not see sufficient evidence to prove any decided diminution*.

On the Direction of Isoclinal Magnetic Lines in Yorkshire. By Professor Phillips.

Observing with reference to the course of the lines of equal dip on the earth's surface that instances occurred, as for example between Ireland and England, of the abrupt flexure or shifting of the lines, for which no reason had been assigned, the author proposed to himself to determine in a part of the North of England the exact course of the isoclinal lines across a country of very peculiar physical conformation, so as to learn how far flexures and breaks of these lines depended on the relative height and mass of elevated land. The direction of the principal masses of high ground in Yorkshire is very favourable to such an inquiry, because the two great hilly regions of the county are separated from each other by a wide, deep, level vale ranging along the actual magnetic meridian; and thus by selecting points in two circles round the city of York as a centre, one constant point of reference could easily be had, and the experiments repeated as often as needed, in order to test completely the dependence of the direction of the magnetic lines on the geological and geographical configuration of the country. The researches, though incomplete, had been carried so far as to give reason to believe that across the two hilly regions and intermediate vale in question the lines of equal dip were not straight, but bent *to the south* in the vale, and turning up to the *north* on the hills. Hence it would appear that the dip of the needle *decreases* as we rise above the surface of the earth, so as to be well recognised at moderate heights. The author proposes to complete his observations on an extended scale, and to add the results of some other experiments contemporaneously made as to the lines of equal (total) magnetical intensity.

On the Direction of the Isoclinal Lines in England.

Professor Lloyd gave a brief account of a series of observations on the direction and intensity of the terrestrial magnetic force, which he had recently commenced in England. The stations of the observations hitherto made extended from the North of Wales to the

* Since this communication was made the calculations alluded to have been performed, and from the agreement of different series made with different needles, both in the Alps and Pyrenees, the author conceives that he has demonstrated the existence of the supposed diminution and approximated to its amount, which is $\frac{1}{1000}$ of the horizontal intensity for every 3000 feet of vertical ascent.

Isle of Wight, and it was proposed to extend the series along the southern and eastern parts of England. From these observations it appeared that the mean direction of the isoclinal lines in England differed materially from the direction of the same lines in Ireland. In England the mean inclination of these lines to the meridian (as deduced from the observations by the method of least squares) appeared to be about 68°, while the corresponding inclination in Ireland amounted to about 57° only. Professor Lloyd then proceeded to state his conviction, that (owing to certain peculiar imperfections of the dipping needle) *differences of dip* at different stations could be ascertained with much greater accuracy than the absolute dips themselves ; and consequently that the *mean direction* of the isoclinal lines, which depended on these differences only, could be determined with more certainty than their absolute position. In reference to this latter point Mr. Fox conceived that his observations warranted him in concluding that there existed a *dislocation* of the lines of equal dip in passing from England to Ireland. It remained still, however, to be examined whether the results of observation may not be adequately represented by a bending of the lines, such as that already noticed ; and Mr. Lloyd expressed his hope of obtaining a sufficient number of observations in other parts of England to throw light upon this curious question.

On the Aurora Borealis. By Wm. Herapath.

From observations made on the 18th November, 1835, the author was led to entertain a different opinion as to the cause and condition of this meteor from that which ascribes it to electrical currents traversing the aerial or ætherial spaces at great heights above the earth's surface.

The phænomena attending the aurora in question were connected with the appearance and movement of clouds, and appeared to the author to originate in the passage of electricity from a charged cloud in the act of *resolving in air* which can receive the resulting water but not the electrical fluid, which consequently while dispersing through a rare atmosphere becomes visible to the eye.

On the Aurora Borealis of 11*th August*, 1836. *By Dr.* Traill

In this aurora a luminous arch, 12° to 15° broad, passed from Corona Borealis through Ursa Major to Auriga, and consisted of short perpendicular cirri or rays, exhibiting the usual fitful horizontal movement. Just below it was a dark cloud-like arched mass, whose upper limb broke into short perpendicular dark cirri, more stationary than the luminous cirri above. Later in the evening a column of amethystine light shot up in the E.N.E., relieved on a dark back ground, tinged of a faint violet colour. About midnight the arched

been of an intense yellow dashed with green, became diffused, and threw off luminous portions which passed the zenith.

Notice of an Instrument to observe minute Changes of Terrestrial Magnetism. *By* W. Ettrick.

The needle, suspended in a glass case by a single fibre or hair, bears a graduated card, which is observed by a telescope properly adjusted at right angles to its surface.

Notice of a new Rubber for an Electrical Machine. *By* W. Ettrick.

On a new Method of Investigating the Specific Heats of Gases. *By* James Apjohn, *M.D., M.R.I.A., Professor of Chemistry in the Royal College of Surgeons, Ireland.*

In the commencement of this communication, which was made orally in the Physical Section, Dr. Apjohn drew attention to some prior researches of his on the same subject, which he had explained at the meeting of the British Association held in Dublin. Having established (see Notices of Communications made at the Dublin Meeting, p. 27.) that the formula $f'' = f' - \frac{48\,a\,d}{e} \times \frac{p}{30}$* includes the solution of the well-known dew-point problem, it follows that $a = (f' - f'') \times \frac{e}{48\,d} \times \frac{30}{p}$, which expression, when the air is perfectly dry, or, what amounts to the same, when $f'' = o$, becomes $a = \frac{fe}{48\,d} \times \frac{30}{p}$. Hence, if f' and d be determined by observation, that is, if the temperature of air t, and the stationary temperature of a wet thermometer immersed in the same medium, first brought to a state of perfect desiccation, be observed, the specific heat of air may be calculated. This formula also, as is obvious, is equally true of the other gases, that is, when applied to similar observations made upon them, it will give their relative specific heats under equal volumes; and such results, it is scarcely necessary to say, when divided by the specific gravities, will give the specific heats under equal weights. Such, as has been already fully explained, was the principle of the method which he had first adopted. The numbers, however, in the last column of the table published by the British Association, (see Notices of Communications made at the Dublin Meeting, p. 32,) are not, as they are represented to be, the specific heats of equal weights, but of equal volumes, for the division by the specific gravities had, through hurry, been omitted. Nor

* f'' and f' are the respective forces of vapour at the dew-point t'', and at t', the stationary temperature of the wet thermometer: d is the depression of temperature shown by the latter instrument, e the caloric of elasticity of aqueous vapour at t', a the specific heat of air, p the existing, and 30 the mean pressure.

do the numbers in question correctly represent the specific heats of the different gases under equal volumes, as given by his experiments; for being unaware of the omission just alluded to, he had erroneously applied to his direct results the correction for the per centage of air ascertained by analysis to be present in each gas. The formula, in fact, for this correction was contrived for the case of specific heats under equal weights, instead of, as it should have been, that of specific heats under equal volumes. When this correction is properly made, the original numbers undergo material modification, as may be seen by inspection of the following table. The original numbers are in column 2, and the corrected ones in column 3.

1.	2.	3.
Air . . .	1·0000	1·000
Nitrogen . .	·9887	·954
Hydrogen . .	1·8948	1·479
Carbonic Oxide .	1·0808	1·037
Carbonic Acid . .	1·0916	1·066
Nitrous Oxide . .	1·1652	1·163

Upon these results, Dr. Apjohn stated that he never placed much reliance. The apparatus employed was very imperfect, particularly in not permitting more than a single experiment with the same quantity of gas; and he also saw reason to doubt that he had, in every instance, by means of it accomplished perfect desiccation. Under these circumstances he had always contemplated returning to the investigation, and towards the latter end of last July he did, in fact, commence a fresh series of experiments, which were conducted on the following plan.

A pair of copper gasometers with glass bells, such as are usually employed by chemical lecturers, were charged with a proper quantity of oil of vitriol instead of water, and placed upon a table, at the distance of three feet from each other, the brass rods attached to the bells being suspended to the extremities of a stout cord passing over a pair of runners fixed in the ceiling of the laboratory. Between the lower stop-cocks a couple of glass tubes were interposed, connected to the stop-cocks by caoutchouc collars, and fitting at their other extremities to each other by a tight ground joint. In the longer of these tubes the dry thermometer was permanently placed, and into it also the wet one was introduced previous to the commencement of an experiment. Matters being, we shall suppose, thus prepared, and the unimmersed bell occupied,—first with atmospherical air,—deprived by the oil of vitriol of its moisture, pressure was made upon it by an assistant so as to force its contents in a rapid current into the second bell, through the tube containing the wet and dry thermometers. During this operation

the observer kept his eye, armed with a lens, steadily fixed on the thermometers, and registered the indications of both as soon as the wet one became perfectly stationary. The height of the barometer being now taken, the necessary data were obtained for calculating from the hygrometric formula $f''=f-\frac{48\,a\,d}{e}\times\frac{p}{30}$, the elastic force of the vapour still existing in the air of the gasometer. The atmospheric air being now replaced by some one of the gases, and this being left sufficiently long in contact with the oil of vitriol, the manipulations and observations just detailed were repeated. This same experiment, with sufficient intervals to allow in each instance of maximum desiccation, was again and again performed; and it having been ascertained, after a considerable number of repetitions, that the results were uniform and consistent, and that they might therefore be relied upon, the mean of all the observations was taken, and from this the specific heat of the gas deduced by means of the formula $a=(f'-f''\times\frac{e}{48\,d}\times\frac{30}{p}$, that value being assigned to f'' which resulted from the preliminary experiment on atmospherical air. The analysis of the gas was next very carefully performed, and it having been ascertained that n volumes, ex. gr., of atmospherical air per cent. were present, the proper correction was applied by the formula $a'=a+\frac{(a-c)\,n}{100-n}$, in which $c=\cdot267$ is the specific heat of air, a' the true specific heat of the gas, and a the specific heat of mixture of gas and air, as previously determined. Such was the course pursued in the case of each of the gases submitted to experiment, and the following are the final results. The numbers represent the specific heats of equal volumes, and, to facilitate comparison, the determinations of Dulong, and those also of De La Roche and Berard, are included in the table.

	J. A.	Dulong.	De La Roche and Berard.
Atmospheric Air . .	1.000	1·000	1·000
Nitrogen	1·048	1·000	1·006
Oxygen	·808	1·000	·976
Hydrogen	1·459	1·000	·903
Carbonic Acid	1·195	1·172	1·258
Carbonic Oxide . .	·996	1·000	1·034
Nitrous Oxide . . .	1·193	1·159	1·350

Having stated his numerical results, and given an outline of the method of investigation which conducted to them, Dr. Apjohn con-

cluded by giving the leading conclusions which he conceives himself justified in deducing from his researches. They are as follows:

1. That the law so much insisted upon in modern times by Haycrapt, Marcet, and De La Rive, and others, that the simple gases have under equal volumes the same specific heat, is not the law of nature.

2. That the more limited proposition enunciated by Dulong, that the simple gases have under a given volume the same specific heat, does not appear true in a single instance, and is altogether at variance with his (Dr. A.'s) result for hydrogen.

3. That the numbers at which he (Dr. A.) has arrived, correspond tolerably well with those of De la Roche and Berard except in the case of hydrogen.

4. That there does not appear to be any simple relation between the specific heats of the gases and their specific gravities or atomic weights, and that philosophers in searching for such are probably pursuing a chimæra.

A paper on the above subject by Dr. Apjohn will shortly appear in the Transactions of the Royal Irish Academy.

On the Impermeability of Water to Radiant Heat. By the Rev. B. Powell, *F.R.S.*

On the Vibration of Bells. By R. Addams.

On an Improved Ear-trumpet. By Charles J. B. Williams, *M.D., F.R.S.*, &c.

Having lately had occasion to examine the ear-trumpets in common use, Dr. W. found them all more or less faulty, especially in that they produce confusing noises, like the roaring in large shells, which render indistinct the articulate sounds which they are intended to convey. On further examination, these disturbing noises were found to consist in:

1. An exaggeration of all the foreign sounds which may happen to accompany the voice, such as the rustling of clothes, reverberations in the room, the rolling of carriages out of doors, &c. This defect is manifestly as inseparable from all instruments which augment sound, as an inefficiency to render distinct an object in a mist is from telescopes.

2. A sound dependent on the longitudinal vibrations proper to the column of air contained in the tube. This sound is the *note* of the instrument as a tube closed at one end, and is therefore deep according to its length and the narrowness of its open end.

3. A sound more or less tinkling or metallic in character, resulting from the transverse vibrations which repeated reflections of sound generate within hollow bodies, and which constitutes the tinkling note produced in the interior of bottles, bladders, and other hollow objects. This sound exists especially in those instruments in which sound is concentrated by repeated reflection from curvilinear surfaces.

Dr. Williams first endeavoured to diminish these disturbing sounds by lateral apertures, which would give exit to the transverse vibrations; but although this plan succeeded to a certain degree, it caused a great loss in the concentrating power of the instrument, the sides of which were no longer uniformly reflective. After many other trials, Dr. W. succeeded in avoiding the above-named defects to a great extent, by combining in an instrument great concentrating power with the greatest simplicity of construction. A conical tube 12 or 15 inches long, its sides forming an angle of 25°, its apex terminating in a short, slightly curved tube adapted to the ear, and its base or open end forming an elliptic aperture, the plane of which forms an angle of about 45° with the axis of the cone, was found to answer best. Such an instrument receives the direct waves of sound in so large a body at its open end, and concentrates them to its narrow end by so few reflections, that the original sound is conveyed, simple and distinct, unmodified by aberrant vibrations, and greatly increased in intensity. It is found to be nearly free from the *roar*; and it increases the intensity of articulate sounds to such a degree, that words spoken only just above a whisper, could by its aid be distinctly heard at a distance of 50 yards during the daytime, and at a much greater distance at night. It rendered the tickings of a watch audible at more than three times the distance at which they could be heard with the unassisted ear.

This instrument may be made of tin plate or other light metal, or, what is better, fine card-board. For the sake of portability, it may be constructed of oiled or gummed silk, folding and unfolding in the manner of an umbrella.

On the higher Orders of Grecian Music. By SAMUEL ROOTSEY, *M.D.*

That the ancients admitted many primes into their expressions of musical intervals is known to the learned, but (the author believes), exclusively from the writings of Ptolemy as edited by Dr. Wallis.

The only three simple and prime ratios admitted by the moderns, are the octave 1 : 2, the fifth 2 : 3, and the major third 4 : 5. Those systems of music of which these form the three bases, the author calls the three lowest orders of music, using this term order in the general sense of mathematicians; the first being that in which the only perfect interval is the octave, the second having the fifths perfect, and the third being our ordinary music as improved by the labours of Smith, Liston, Farey, Chladni, and others.

The number of small intervals, called semitones, brought into use by the adoption of these bases, is seven.

Besides the above semitones, the ancients used many others which Dr. Burney believes are, to modern ears, perfectly intolerable. Some of those notes by which these Greek intervals are formed are frequently heard upon certain instruments, such as the trumpet; but having a most peculiar character, and differing so widely from the notes of the piano

forte and organ as now tuned, they are altogether rejected, and pronounced discordant, although in fact they would occasion no beating in an organ perfectly tuned.

The object of this paper was to show that they are improperly discarded, and that as they characterize the sweetest concords, as they are therefore required by the ear, and are constantly practised by the best voices, it is worth while to inquire more into the consequence of adopting them wherever it is possible, and of teaching their extensive use in every school of Music.

Plutarch, Boëthius, and all the authors whose writings are collected by Meibomius, viz., Aristoxenus, Euclid (Introductio Harmonica), Nicomachus, Alypius, Gaudentius, Bacchius, Aristides, Quintilianus, and Martianus Capella, explain none of these higher orders, but Ptolemy in his Harmonics proves that Archytas, Eratosthenes, and Didymus, as well as himself, used them continually.

Far from agreeing with Dr. Burney that two tones and two semitones are all that are useful, and that eleven ancient intervals are impracticable, Dr. Rootsey endeavoured to show that 30 intervals, namely 8 tones and 22 semitones, are required by a modern ear, and are daily practised on the voice and violin; they ought therefore to be universally understood and appreciated by all contrapuntists and professors of the science of music.

On Mnemonical Logarithms. *By* Samuel Rootsey, *M.D.*

In this communication the author described and exemplified the use of certain low numbers, which serve to compare the simpler ratios with sufficient accuracy for many purposes, and thus, when fixed in the memory, to supply occasionally the want of a table of logarithms.

Experiments on the Weight, Height, and Strength of Men at different Ages. *By Professor* Forbes.

These experiments, on above 800 individuals, students in the University of Edinburgh, were entirely made personally by the author, with a view to the extension of M. Quetelet's general results and to the comparison of the physical development of different nations. Of the persons measured, (who were chiefly between the ages of 15 and 25,) nearly two thirds were natives of Scotland, and in the calculation of averages these were kept apart, as were the English and Irish. The leading results were these:

1. The form of the curves indicating the law of development with age, remarkably coincide with those of M. Quetelet. The attainment of full growth seems (as in his experiments) to be scarcely complete even at the age of 25.

2. The development of the Scotch in the particulars of weight, height,

and strength seems much greater than that of the Belgians (taken from persons of a similar class).

3. So far as the limited results for the English and Irish are worthy of confidence, (and they agree in all the three particulars just specified,) the English are less developed than the Scotch, but more than the Belgians,—the Irish more developed than either.

4. The mean weight, height, and strength of a Scotchman 25 years of age appears to be (from above 500 experiments used in approximating to the curve), weight 152·5lbs., height 69·3 inches, strength of muscles of the back by Regnier's dynamometer 420lbs.

The Rev. W. Whewell gave a further account of his Anemometer, previously exhibited and described by him, the instrument being now completed and put in operation. It consists of a small wind wheel, (like a windmill with eight sails,) which is kept towards the wind by a vane. The rapid rotation of the wheel is, by a train of toothed wheels and screws, converted into a slow vertical motion, which carries a pencil downwards, tracing a line on the surface of a vertical cylinder, having the axis of the vane for its axis. The extent of vertical motion shows the amount of the wind, and the part of the circumference of the cylinder on which the trace lies, shows the direction.

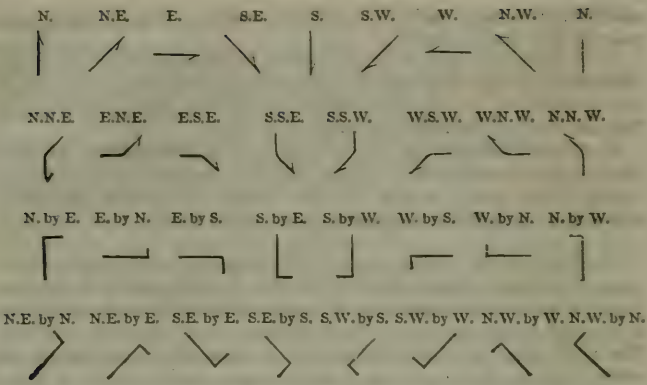
The observation is made by clamping the vane, so that a vertical scale (of tenths of an inch) coincides with the mean direction of the trace; the amount of wind may then be read off on the scale, and the direction on a circle of the cylinder.

Mr. Whewell proposed that the wind should be registered by writing the directions of the compass which it successively assumed, and beneath each direction the amount of wind in that direction shown by the scale. Thus:

The observations in July, 1836, were

July 1.	S.E.	S.E. by E.	S.S.E.
	12	4	4
— 2.	S.W.		
	6		
	W.S.W.		
— 3. } — 4. }	28		
— 5.	S.E. by S.		
	22		
— 6.	S.E. by E.	S. by E.	
	10	8	

But the common notation for the points of the compass is inconvenient, from its not showing at once the relation between the different directions. Mr. Whewell proposes the following notation:



It was also proposed that the wind thus registered should be denoted in another manner, for the purpose of showing the combined result of the wind of a considerable period, as a year. This is to be done by beginning from a point in a plane (as a sheet of paper) on which the directions of the compass are supposed to be represented; then, drawing a line in the direction of the first wind, and of a length proportional to the quantity of wind; from the extremity of this line, drawing another in the direction of this wind and proportional to its quantity; from the extremity of this another, and so on. The broken line thus obtained will represent the course of the wind for the whole time.

If the course of the wind be thus represented for a year, and then for another year, and so on, there will be a general resemblance among the lines so drawn, because we have, in general, the same winds at the same seasons. The curve line which is the mean of all these lines, or from which they may all be considered as slight deviations, may be called the *annual type* of the wind. It is very different in different places, as has been observed by writers on meteorology (Kämtz and others). But there has hitherto been no means of obtaining this course with any degree of correctness, for want of an instrument which could register at the same time the direction and amount of the wind. By means of the present instrument, it is conceived that this difficulty is, in a great measure, overcome.

One of Mr. Whewell's anemometers is erected at Cambridge, and will be observed regularly. Another will be erected at York, and another at Plymouth; and the observations will be communicated to the ensuing Meetings of the Association.

It is very desirable that instruments of the same construction, and the same scale, should be erected and observed at other places. Mr. Whewell offers all the assistance in his power to those who are willing to construct and employ this instrument.

On the Connexion of the Weather with the Tide. By G. WEBB HALL.

From long observations in the vicinity of Bristol, the author has inferred the following laws of phænomena there occurring.

1. The barometer generally undulates at times corresponding with the changes of the moon, and more frequently sinks than rises.

2. The weather is generally unsettled at these periods, continuing so for about two days; high winds also prevail.

3. The weather, having become determinate after such unsettled state, retains the character which it assumes till the next change of the moon.

4. These variations are found to obtain, not only at the full and new moon, but at the quarters.

5. The period from whence the weather assumes a determinate character is coincident with the occurrence of spring and neap tides.

On Lucas's Method of Printing for the Blind. By Rev. L. CARPENTER*.

On the Ratio of the Resistance of Fluids to the Velocity of Waves. By J. S. RUSSELL, *Esq.*†

Calculus of Principal Relations. By Professor Sir W. R. HAMILTON.

The method of principal relations is an extension of that mode of analysis which Sir William Hamilton has applied before to the sciences of optics and dynamics; its nature and spirit may be understood from the following sketch.

Let $x_1, x_2, \ldots x_n$ be any number n of functions of any one independent variable s, with which they are connected by any one given differential equation of the first order, but not of the first degree,

$$o = f(s, x_1, \ldots x_n, ds, dx_1, \ldots dx_n), \qquad (1)$$

and also by $n-1$, other differential equations, of the second order, to which the calculus of variations conducts, as supplementary to the given equation (1), and which may be thus denoted:

$$\frac{f'(x_1) - d f'(dx_1)}{f'(dx_1)} = \ldots = \frac{f'(x_n) - d f'(dx_n)}{f'(dx_n)}; \qquad (2)$$

Let, also, $a_1, \ldots a_n$ be the n initial values of the n functions $x_1, \ldots x_n$, and let $a'_1, \ldots a'_n$ be the n initial values of their n derived functions or differential coefficients $x'_1 = \frac{dx_1}{ds}, \ldots x'_n = \frac{dx_n}{ds}$, corresponding to any assumed initial value a of the independent variable x. If we could integrate the system of the n differential equations (1) and (2), we should thereby obtain n expressions for the n functions $x_1, \ldots x_n$, of the forms

* In consequence of the request made to the Rev. William Taylor to complete a General Report on the processes of Printing for the Blind, it has been deemed unnecessary to give an unconnected abstract of Mr. Lucas's ingenious researches.

† The Author is engaged in special researches to complete his views on the subject of waves, at the request of the Association.

$$\left.\begin{array}{l} x_1 = \varphi_1 (s, a, a_1, \ldots a_n, a'_1, \ldots a'_n), \\ \ldots\ldots\ldots\ldots\ldots \\ x_n = \varphi_n (s, a, a_1, \ldots a_n, a'_1, \ldots a'_n); \end{array}\right\} \quad (3)$$

and, by the help of the initial equation analogous to (1), might then eliminate $a'_1, \ldots a'_n$, and deduce a relation of the form

$$o = \psi (s, x_1, \ldots x_n, a, a_1, \ldots a_n); \quad (4)$$

that is, a relation between the initial and final values of the $n + 1$ connected variables $s, x_1, \ldots x_n$. Reciprocally, the author has found that if this one relation (4) were known, it would be possible thence to deduce expressions for the n sought integrals (3) of the system of the n differential equations (1) and (2), or for the n sought relations between $s, x_1, \ldots x_n$, and $a, a_1, \ldots a_n, a'_1, \ldots a'_n$, however large the number n may be; in such a manner that all these many relations (3) are implicitly contained in the one relation (4), which latter relation the author proposes to call on this account the *principal integral relation*, or simply, the PRINCIPAL RELATION, of the problem.

For he has found that the n following equations hold good,

$$\frac{f' (ds)}{\psi' (s)} = \frac{f' (d x_1)}{\psi' (x_1)} = \ldots = \frac{f' (d x_n)}{\psi' (x_n)}; \quad (5)$$

which may be put under the forms

$$\left.\begin{array}{l} a_1 = \varphi_1 (a, s, x_1, \ldots x_n, x_1', \ldots x'_n), \\ \ldots \\ a_n = \varphi_n (a, s, x_1, \ldots x_n, x'_1, \ldots x'_n), \end{array}\right\} \quad (6)$$

and are evidently transformations of the n sought integrals (3). And with respect to the mode in which, without previously effecting the integrations (3), it is possible to determine the *principal relation* (4), or the *principal function* which it introduces, when it is conceived to be resolved, as follows, for the originally independent variable s,

$$s = \varphi (x_1, \ldots x_n, a, a_1, \ldots a_n), \quad (7)$$

the author remarks that a partial differential equation of the first order may be assigned, which this principal function φ must satisfy, and also an initial condition adapted to remove the arbitrariness which otherwise would remain. In fact the equations (5) may be thus written,

$$\frac{\delta d s}{\delta d x_1} = \frac{\delta s}{\delta x_1}, \ldots \frac{\delta d s}{\delta d x_n} = \frac{\delta s}{\delta x_n}, \quad (8)$$

in which

$$\frac{\delta d s}{\delta d x_i} = -\frac{f' (d x_i)}{f' (d s)}, \text{ and } \frac{\delta s}{\delta x_i} = \varphi' (x_i), \quad (9)$$

and since, by (1), there subsists a known relation of the form

$$o = F \left(s, x_1, \ldots x_n, \frac{\delta d s}{\delta d x_1}, \frac{\delta d s}{\delta d x_n}\right), \quad (10)$$

the following relation also must hold good,

$$o = F \left(s, x_1, \ldots x_n, \frac{\delta s}{\delta x_1}, \ldots \frac{\delta s}{\delta x_n}\right), \quad (11)$$

that is, the principal function ϕ must satisfy the following partial differential equation of the first order,

$$o = F\left(\varphi, x, \ldots x_n, \varphi'(x_1), \ldots \varphi'(x_n)\right); \qquad (12)$$

it must also satisfy the following initial condition,

$$o = \lim_{s=a} . f(a, a_1, \ldots a_n, \varphi - a, x_1 - a_1, \ldots x_n - a_n). \qquad (13)$$

Such are the most essential principles of the new method in analysis which Sir William Hamilton has proposed to designate by the name of the *Method of Principal Relations*, and of which, perhaps, the simplest *type* is the formula

$$\frac{\delta\, d s}{\delta\, d x} = \frac{\delta s}{\delta x}, \qquad (14)$$

to be interpreted like the equations (8).

The simplest *example* which can be given, to illustrate the meaning and application of these principles, is, perhaps, that in which the differential equations are

$$o = \left(\frac{d x_1}{d s}\right)^2 + \left(\frac{d x_2}{d s}\right)^2 - 1, \qquad (1)'$$

and

$$\frac{d\, d x_1}{d x_1} = \frac{d\, d x_2}{d x_2}, \qquad (2)'$$

Here, ordinary integration gives

$$x_1 = a_1 + a'_1 (s - a), \; x_2 = a_2 + a'_2 (s - a); \qquad (3)'$$

and consequently conducts to the following relation, (in this case the *principal* one,)

$$o = (x_1 - a_1)^2 + (x_2 - a_2)^2 - (s - a)^2, \qquad (4)'$$

or

$$s = a + \sqrt{(x_1 - a_1)^2 + (x_2 - a_2)^2}, \qquad (7)'$$

because, by (1)', we have

$$a'^2_1 + a'^2_2 = 1;$$

it enables us therefore to verify the relations (8), or (14), for it gives

$$\frac{\delta s}{\delta x_1} = \frac{x_1 - a_1}{s - a} = \frac{d x_1}{d s} = \frac{\delta\, d s}{\delta\, d x_1},$$

and, in like manner,

$$\frac{\delta s}{\delta x_2} = \frac{\delta\, d s}{\delta\, d x_2}.$$

Reciprocally, in this example, the following known relation, deduced from (1)',

$$o = \left(\frac{\delta\, d s}{\delta\, d x_1}\right)^2 + \left(\frac{\delta\, d s}{\delta\, d x_2}\right)^2 - 1, \qquad (10)'$$

would have given, by the principles of the new method, this partial differential equation of the first order,

$$o = \left(\frac{\delta s}{\delta x_1}\right)^2 + \left(\frac{\delta s}{\delta x_2}\right)^2 - 1, \qquad (11)'$$

which might have been used, in conjunction with the initial condition

$$o = \lim_{s = a} \left\{ \left(\frac{x_1 - a_1}{s - a}\right)^2 + \left(\frac{x_2 - a_2}{s - a}\right)^2 - 1 \right\}, \qquad (13)'$$

to determine the form (7)′ of the principal function s; and thence might have been deduced, by the same new principles, the ordinary integrals (3)′, under the forms

$$a_1 = x_1 + a'_1 (a - s),\ a_2 = x_2 + a'_2 (a - s). \qquad (6)'$$

In so simple an instance as this, there would be no advantage in using the new method; but in a great variety of questions, including all those of mathematical optics, and mathematical dynamics, (at least, as those sciences have been treated by the author of this communication,) and in general all the problems in which it is required to integrate those systems of ordinary differential equations (whether of the second or of a higher order) to which the calculus of variations conducts, the method of principal relations assigns immediately a system of finite expressions for the integrals of the proposed equations, an object which can only very rarely be attained by any of the methods known before. It seems, for example, to be impossible, by any other method, to express rigorously, in finite terms, the integrals of the differential equations of motion of a system of many points, attracting or repelling one another; which yet was easily accomplished by a particular application of the general principles that have been here explained*. The author hopes to present these principles in a still more general form hereafter.

CHEMISTRY.

On the Chemical Nomenclature of Berzelius. By R. Hare, *M.D., Professor of Chemistry in the University of Pennsylvania.*

Berzelius has divided those bodies which by union with a radical produce salts, and those which are capable of entering into saline combinations both as acids and bases, into two classes, designated as *Halogen* and *Amphigen*. Dr. Hare stated his objections to this classification, remarking especially on the ambiguity of the terms *salts, acids,* and *bases*. He would distinguish all electro-negative compounds by subjoining the termination *acid*, and all electro-positive compounds, formed either by *halogen* or *amphigen* bodies, by subjoining the termination *base*, and confine the use of the termination *ide* to those compounds of which the electrical habitudes are indeterminate: he proposed to substitute the terms chlorohydric, sulphohydric, &c., for hydrochloric and other analogous words; and on this point stated that the opinion of Berzelius coincides with his own.

* See *Philosophical Transactions* for 1834 and 1835; also, *Report* of Edinburgh Meeting of the British Association.

On a Calorimotor for Igniting Gases in Eudiometrical Experiments, and Gunpowder in Rock-blasting. By R. Hare, *M.D.*

This is a galvanic instrument of two pairs, for producing ignition at a distance from the apparatus : when it is an object to produce ignition at a greater distance, Dr. Hare resorts to analogous apparatus of larger size and consisting of four pairs.

By means of potassium ignited by this instrument, Dr. Hare has been enabled extemporaneously to evolve silicium or boron from fluo-silicic or fluo-boric acid gas.

He has also been enabled to explode gunpowder at a great distance. In one instance, twelve charges had been exploded at 150 feet from the calorimotor employed.

A projector of the name of Shaw had attempted to effect the explosion of gunpowder by means of the Leyden jar, for the purpose of rock blasting, but finding mechanical electricity too precarious, had applied to Dr. Hare for means of rendering his process more certain, and this had led to the following contrivance. Two iron wires of about the size No. 40, and one of the finest kind were twisted together, and the larger afterwards nipped, so as to leave a small portion of the fine wire uncut between their nipped extremities. All the wires were secured in a saw kerf in a piece of hard wood, having a small hole filled with a fulminating powder, consisting of arsenic and chlorate of potash, through which the fine wire passed. The powder was secured by paper pasted on by means of gum arabic. One termination of the twisted wire was soldered to a dish of tinned iron, by which the lower end of a tube of the same material was closed. The tube being then filled with gunpowder was closed by a cock, through which the upper end of the twisted wire was made to pass. To the outside of the tin tube a strip of metal or a wire was soldered. By connecting these wires with the poles of a calorimotor, ignition of the gunpowder in the tube might be effected at every distance, or in any situation, and as well under water as above it.

Many accidents had happened in the ordinary mode of blasting, from causes which could not be operative in the use of the means above described. The principal source of danger is the liability of the gunpowder to explode during the ramming of it into the perforated rock, or before the workmen had time to get out of the way.

In Dr. Hare's method, the gunpowder being inclosed in a metallic tube previously to its introduction into a perforated rock, is not liable to ignition from the process of ramming.

Dr. Hare conceives that the intervention of the fulminating powder would greatly accelerate the combustion, and of course increase the force of the explosion.

On the Aqueous Sliding-rod Hydrogen Eudiometer. *By* R. Hare, *M.D.*

In this instrument measurements are effected by the ingress or regress of a graduated rod pressing air-tight through a collar of leather into a copper tube, at the extremity of which a glass receiver is situated. This receiver terminates in an apex, with a capillary opening, which is closed by a valve at the end of a lever actuated by a spring, when the effect of the latter is not counteracted by the hand. The cavity of the instrument being filled with water, and being perfectly air-tight, if the rod be withdrawn to any sensible extent, while the orifice at the apex of the receiver is closed, a vacuum ensues ; but if that orifice be open the resulting vacuity becomes filled with the air, or with any other gas by which it may be surrounded.

To analyse the air, it is only necessary to take into the receiver, in the first instance, one hundred measures of that fluid, and then introducing the apex into a bell glass containing hydrogen, to draw into the receiver about fifty measures or more of this gas. By means of an arch of platina wire within the receiver, so situated as to become the medium of a galvanic discharge, the gaseous mixture being inflamed, and all the oxygen, with twice its bulk of the hydrogen, consequently condensed, on introducing the instrument into water, so that the apex may be just below the surface, the deficit produced by the combustion is replaced by water ; and hence, on returning the rod carefully only so far as to expel the residual gas, the number of graduations which remain without the tube indicates the extent of the condensation. Of this, one third is due to oxygen.

Dr. Hare also exhibited some volumeters, or volume measures, by which equal volumes of a gas may be taken with great accuracy.

By means of one of these instruments a mixture of one part of hydrogen and two of air being introduced into a bell over the pneumatic trough, on taking into the eudiometer 150 measures, and proceeding as already described, the same results may be obtained, and perhaps with more accuracy.

As the pressure of the spring upon the valve, through the medium of the lever, is not sufficient to resist the force of the explosion, the instrument is furnished with a kind of staple, moving on a hinge, and furnished with a screw. By these means the valve is firmly held in its place as long as is requisite, and afterwards easily released by relaxing the pressure of the screw and moving the staple on its hinge, so as to get it out of the way of the lever, of which the extremity bearing the valve is then easily raised by the pressure of the hand.

The average results of some hundreds of experiments performed by Dr. Hare with various instruments, as well as with that above described, would lead to the conclusion that the quantity of oxygen in 100 measures of air is $20\frac{66}{100}$.

Dr. Hare also presented to the Members of the Chemical Section printed copies of a series of essays, not yet published, on different subjects of chemical and electrical science, and descriptive of various improvements in philosophical apparatus.

Electrical Experiments. *By* ANDREW CROSSE, *Esq.*

Mr. Crosse gave an account of some experiments which he had made on the effect of long-continued galvanic action of low intensity in forming crystals and other substances analogous to natural minerals. At the time when he first commenced these experiments he had not heard of those by which M. Becquerel had previously arrived at similar results. A few weeks afterwards he was informed by a friend that that philosopher had produced sulphurets of lead and silver by electric action, but his account of the mode of conducting his experiments had not been seen by Mr. Crosse. "It is but due to myself," Mr. Crosse adds, "to mention that I attended the meeting at Bristol without the least intention of intruding on the notice of the Association, well knowing how incomplete my experiments were; and had it not been for the advice of some friends whom I met there, I should not have presumed to offer any communication till I had gone further into the matter."

Mr. Crosse stated that by passing a galvanic current from batteries with various combinations of plates excited by water only, through solutions of carbonate of lime, he obtained rhomboidal crystals of that substance deposited round the negative pole. Having in one of these experiments kept a piece of *scouring brick* moistened with the solution for four or five months, at the expiration of that time he found very fine prismatic crystals (which he took for arragonite) deposited on that part of the brick which lay contiguous to, without actually touching, the positive pole, whilst what he considered as common carbonate of lime was confined to the negative pole. In a similar experiment made on fluo-silicic acid, after a deposit of lead at the *negative* pole, minute crystals, which he considered as siliceous, made their appearance at the extremity of the deposit of lead, and, on the removal of the lead, at the *positive* pole: a crystal which was a transparent hexahedral prism terminated with a similar pyramid, but which however was too soft to scratch glass, was removed at the end of two or three months from the bottom of the piece of brick; a second well-formed crystal, measuring $\frac{3}{16}$ of an inch in length by $\frac{1}{16}$ in breadth, after being put in a dry place for one or two months, scratched glass readily. Mr. Crosse made similar experiments on solutions of silicate of potash and obtained imperfect hexahedral crystallizations, which he judged to be siliceous, and in some instances chalcedonic deposits. The following is a list of mineral substances which he considered himself to have formed by electrical action in addition to those above-mentioned:—Red oxide of copper in octahedrons opake and transparent, crystals of copper and silver in cubes and octahedrons, crystallized arseniate and carbonate of copper, phosphate and grey sulphuret of ditto, sulphuret of silver, crystallized carbonate of lead, yellow oxide of lead, mammillated carbonate of lime, oxide of lime, mammillated black oxide of iron, sulphuret of iron, sulphuret of antimony (Kermes mineral), crystallized sulphur.

Between three and four years ago Mr. Crosse made a set of experiments on the voltaic battery, and found the power to be considerably increased when each copper plate of the one pair was brought into all-

but contact with the zinc plate of the other pair, but that the insulation of each separate pair of plates was of still greater efficacy. He put together 1200 pairs of zinc and copper cylinders on this plan, filled with water alone, and found the effects as follow: the average size of the cylinder being about equal to a four-inch plate, four pairs communicate a charge to an electrical battery sufficient to cause iron wire barely to scintillate, and will just decompose water; 100 pairs cause the gold leaves of an electrometer to diverge $\frac{1}{3}$ of an inch; 200 pairs open the same $\frac{2}{3}$ of an inch; 300 pairs cause the same to strike their sides, and fire gunpowder placed loosely on a brass plate, the opposite poles being connected with an electrical battery; 500 pairs give a smart shock, fire gunpowder readily, give a visible stream of fire to the dry fingers, and *cauterize* the skin as though with a red-hot wire; 1200 pairs being connected with an electrical battery fuze the point of a penknife, deflagrate brilliantly metallic leaves, tin-foil, and even stout silver sheeting, &c., &c. Mr. Crosse has used a battery of this kind for eighteen months without any sensible diminution of power. These batteries are well calculated for electrical crystallization, and from ten to fifty pairs of insulated cylinders Mr. Crosse thinks would answer every purpose of that sort.

Another subject noticed by Mr. Crosse was atmospheric electricity; he has for many years paid considerable attention to this part of the science, and taken great pains in extending on lofty poles and insulating with all possible care a copper wire $\frac{1}{15}$ of an inch diameter and 300 feet long. The experiments made with this resemble in general those made on a smaller scale by other experimenters. Mr. Crosse considers a thunder cloud to be divided into zones of alternate positive and negative electricity. It appears to him that a nucleus is first formed of one electricity, then a layer or zone of the *opposite*, and so on weaker and weaker to the circumference. There are occasionally electric fogs nearly as powerful as a small thunder cloud. Mr. Crosse has known during five hours a stream of alternate positive and negative electricity pour from the atmospherical conductor during a fog, and driving rain sufficient to fuze a considerable length of strong wire. These electrical fogs appear to be composed of alternate positive and negative columns.

Remarks on the Results of some Experiments on the Phosphate and Pyro-Phosphate of Soda. By Henry Hough Watson.

Mr. Watson's attention having been drawn to the discordant statements given by different authors of the proportions of acid and base in the salt called phosphate of soda, viz., in the dry state, he was induced to investigate the subject by experiment. On putting to the test the experiment which Dr. Thomson gives, page 199, vol. i. *First Principles of Chemistry*, of mixing a solution of 7·5 grains of anhydrous phosphate of soda with one of 20·75 grains of crystals of nitrate of lead, the result was not an entire decomposition of each salt, but a little of the nitrate of lead remained undecomposed.

Having exposed a quantity of gradually dried phosphate of soda to a bright red heat, he weighed out 30 grains while nearly red hot, dissolved it in water, and added to it a solution of 83 grains of crystals of nitrate of lead,—proportions equivalent to those which Dr. Thomson used, and half the numbers which are generally used to indicate the atomic weights. The mixture was well agitated; a precipitate of phosphate of lead formed, which was washed, dried, exposed to a low red heat, and weighed; the liquor from which it was separated gave a precipitate of sulphate of lead by the addition of sulphate of potash. The mean of four nearly agreeing experiments gave phosphate of lead 66·96 grains, and sulphate of lead 4·42 grains. Now 4·42 sulphate of lead $=$ 4·82 nitrate of lead; and $83 - 4{\cdot}82 = 78{\cdot}18$ nitrate of lead spent in producing the precipitate of phosphate.

The acid in 78·18 nitrate of lead being capable of neutralizing 15·07 soda, and the liquor when freed from lead by sulphate of potash being neutral to the litmus test, it follows that 30 grains of anhydrous pyrophosphate of soda are constituted of 15·07 soda and 14·93 acid; and the atomic weight of soda being 32, that of the acid in pyrophosphate of soda must be 31·7.

One hundred grains of the crystals of the ordinary phospate of soda, by being placed under the exhausted receiver of an air-pump with a vessel of sulphuric acid, are reduced to 39·65 grains; and the residue, by exposure to a red heat, is reduced to 37·1 grains. From this and the result of the above-mentioned experiments Mr. Watson infers that the quantity of soda in 100 grains of crystals of the ordinary phosphate is 18·63 grains, and that the quantity of acid is 18·47 grains.

Mr. Watson having decomposed both the ordinary uncalcined phosphate of soda and the pyrophosphate with lime water, found that the quantity of lime which sufficed to saturate a proportion of the latter was not sufficient to saturate a corresponding proportion of the former. From this and other circumstances of the analysis Mr. Watson is led to suspect that the phosphate of soda when dried as much as possible in the exhausted receiver is rendered anhydrous, and that when afterwards exposed to a red heat a partial decomposition of the acid takes place; and this opinion he thinks strengthened by the consideration that though no gas, nor anything but water, can be collected in converting the phosphate into pyrophosphate, a peculiar burnt smell is given out; and if the calcination of the salt (*it having been previously dried gradually*) be effected in a glass tube, the salt may be observed to acquire a carbonaceous tinge during the operation, which, however, vanishes by a continuation or perhaps rather an increase of the heat. He also adds, that though it has been asserted that a solution of the pyro-salt becomes changed, by keeping, into the ordinary phosphate, such has not been the case with a solution which he has kept from the 14th December, 1835, till now, in order to prove the fact; for it still continues to give a precipitate *as perfectly white* with nitrate of silver as it did when newly prepared.

Mr. Watson adds that there is a peculiar difference in appearance between the calcined precipitate obtained from the pyrophosphate and lime water, and the calcined precipitate obtained from the ordinary phos-

phate and lime water. Both precipitates are *white* when dried as much as possible at a low temperature; but that from the pyrophosphate becomes *black* if exposed to a red heat, while the other by the same treatment retains its whiteness.

When in the course of these experiments crystals were the subject of operation, Mr. Watson took care to use such as were neither damp nor effloresced. To manage this he powdered a quantity of large crystals, and then intimately mixed them with so much water as rendered them decidedly damp; he then spread them very thinly over a flat surface in a room where the force of vapour in the atmosphere was not so much as 0·15 of an inch of mercury less than it would have been if the atmosphere was saturated with vapour, and left them in that state until they discontinued to lose weight, an atmosphere of this drying power being incapable of depriving the salt of any of its water of crystallization.

Extracts from a Paper "on Important Facts obtained Mathematically from Theory, embracing most of those experimental results in Chemistry, which are considered as ultimate facts." By THOMAS EXLEY, *A.M.*

Mr. Exley observed that his object was to place chemistry under the domain of mathematical science, and to establish a new theory by legitimate but easy calculations.

The principles of the theory are: 1. That every atom of matter consists of an indefinitely extended sphere of force, varying inversely as the square of the distance from the centre; and that this force acts *towards* the centre and is called *attraction* at all distances except in a small concentric sphere, in which it acts *from* the centre and is called repulsion.

2. That there is a difference in atoms arising from a difference in their absolute forces, or in the radii of their spheres of repulsion, or in both these.

The attraction is the same as that of gravitation in the theory of Newton or that of Boscovich; but in both these theories, where gravitation ends a series of alternations of attraction and repulsion varying by unknown laws commences; Newton closes with a solid, Boscovich with a sphere of repulsion varying inversely as the distance. Mr. Exley considers that his theory differs in every particular from both these in the spaces where chemistry and its connate sciences are concerned, and does not like them launch into the regions of conjecture.

The first principle, as far as regards the attraction, is really true in nature; nothing in physics is better established. It is equally certain from phænomena that there is some repulsion near the centre of atoms; the law of its variation has not been determined, but the order of nature, the inductive procedure, obliges us, in the absence of every contradictory phænomenon, to continue the law of gravitation. As well may we contend that there is no force of gravitation in spaces where no particular observations have been made, as to say that the same force does not exist in the sphere of repulsion, in the law of force—in the quantity of force, there is no violation of the law of continuity; the direction only changes *per saltum*, which is quite as easy to conceive as a

change by continuous degrees, as Newton and Boscovich suppose, and which breaks the continuity in the law of force.

The second principle is, the author thinks, as simple and as natural as can well be conceived, and an evident result from phænomena and the first principle.

It was stated in a treatise lately published by the author, that nature presents two classes of atoms, the one comprehending ponderable matter, such as oxygen, carbon, &c., which adhering with great tenacity may be called tenacious atoms (till a better name be found). The other consists of atoms which manifest their existence by motions and actions under a form which has been called æthereal; hence they may be denominated æthereal atoms; they comprehended the electric fluid, caloric, and light.

In the same work the atoms of the electric fluid were considered as having a much greater absolute force than those of caloric and light. This has been confirmed by subsequent observations, entitling the electric atoms to the rank of an intermediate class, so that we may distinguish atoms into three classes, tenacious, electric, and æthereal, not differing in nature but only by a marked difference in their absolute force. Of the 1st and 3rd classes there are many sorts, but of the electric fluid probably only one sort.

The weights of the other atoms used in this paper are taken from Dr. Thompson's determinations. Respecting carbon, whose weight, according to Dr. Thompson, is 12 (taking oxygen 16), and according to Berzelius it is $12\frac{1}{4}$, the specific gravities are calculated on both suppositions, and then compared with those found by experiment in the following table:

Name.	Atomic Weight	Sp. Gr. by cal.	Sp. Gr. by exper.	Authority.
Carbonic Oxide....	12	·9721	·9732	Thenard and Berzelius, mean,
	$12\frac{1}{4}$	·9895		1st, ·0011 in defect; 2nd, ·0163 excess.
Carbonic Acid.....	12	1·5277	1·5213	Thenard and Gay Lussac, mean,
	$12\frac{1}{4}$	1·5451		1st, ·0064 excess; 2nd, ·0238 excess.
Light Carburetted	12	·5555	·5590	Dr. Thompson.
Hydrogen......	$12\frac{1}{4}$	·5728		1st, ·0035 defect; 2nd, ·0138 excess.
Alcohol..........	12	1·5972	1·6133	Gay Lussac.
	$12\frac{1}{4}$	1·6319		1st, ·0161 defect; 2nd, ·0186 excess.
Ætherine........	12	1·9444	1·9100	Dr. Faraday.
	$12\frac{1}{4}$	1·9791		1st, ·0344 excess; 2nd, ·0691 excess.
Æther	12	2·5694	2·5830	Gay Lussac and Desprez, mean.
	$12\frac{1}{4}$	2·6388		1st, ·0136 defect; 2nd, ·0588 excess.
Naphtha..........	12	2·8472	2·8330	Saussure.
	$12\frac{1}{4}$	2·8993		1st, ·0142 excess; 2nd, ·0663 excess.
Naphthaline......	12	4·4444	4·5280	Dumas.
	$12\frac{1}{4}$	4·5312		1st, ·0836 defect; 2nd, ·0032 excess.
Paranaphthaline ...	12	6·6666	6·741	Dumas.
	$12\frac{1}{4}$	6·9270		1st, ·0074 defect; 2nd, ·1860 excess.
Camphene........	12	4·7222	4·7670	Dumas.
	$12\frac{1}{4}$	4·8090		1st, ·0348 defect; 2nd, ·0420 excess.

The author assigns reasons for adopting 16 as the atomic weight of oxygen, when that of hydrogen is taken = 1.

It is seen that the calculated specific gravity exceeds that found by experiment in three of the ten compounds even when carbon is 12; in all cases there is an excess when $12\frac{1}{4}$ is used; and except in naphthaline the defect is always much less than the excess, which gives the preference to 12 for the atomic weight of carbon.

The author next proceeds to deduce from the theory important facts which are already known to chemists as ultimate results of their experiments. These are embodied in eight propositions with corollaries, of which the last is here given.

Prop. 8. Taking each elementary atom as representative of a volume, then in all strictly chemical combinations, that is, whenever there is a condensation, the resulting volume is always, without exception, either one or two volumes exactly. Since after combination the volume is diminished, the centre of some atom, or those of several atoms, have penetrated the atmospherule of some other (prop. 3 and cors.)

1. When the atmospherule of one atom or single group is penetrated by the centres of all the others, the result is a single group, (def. 1.) and consequently (prop. 3, cor. 1) the result will be one volume exactly.

2. When the atmospherule is not penetrated by all the centres of the others, then one or more of the atoms will be brought by their mutual actions to the interval between the two remaining atoms, or single groups, which combine, and thus situated, will (prop. 3, cor. 3) supply the effect of the æthereal matter, which it displaces; hence the whole will form a double group, and (same cor.) will become two volumes exactly.

3. When one atom or single group combines with a double group, the centres of the combining atoms will penetrate the atmospherule of the double group, otherwise there would be only cohesive combination; hence the compound will continue a double group, and form two volumes (prop. 3, cor. 3), except when the mutual actions bring all the centres within the sphere of repulsion of one of them, thus constituting one volume (prop. 3, cor. 1). Hence still we shall have either a single or double group, and it is, from this, evident that no other case can occur; therefore the resulting volume will be always exactly one or two, however many volumes combine.

Cor. This prop. embraces, simplifies, and extends the theory of volumes.

Having deduced this remarkable law from theory, it became important to know if such an unexpected result be true in fact or not. To determine this point Mr. Exley carefully examined all the compound gases and vapours, whose specific gravities had been obtained by experiment, as far as he could find them in the best authors. These, to the amount of fifty-seven, are inserted in the following table. The specific gravities are calculated according to this law, from the atomic weights as given by Dr. Thompson, doubling some of his numbers to correspond with oxygen 16, and in every instance they agree within the allowable limits of unavoidable errors in experiments of that kind, except in boro-

chloric acid, which, says Dr. Thompson, requires further investigation, and a small discrepancy in oil of turpentine, a substance difficult to procure in a perfect state.

Table of the varieties of Chemical Compounds, with their Elements and Specific Gravities in the form of Gas or Vapour.

Name.	Nos. and Weights of Elements.		Wt. of Atom.	Vol.	Sp. Gr. hy.=1	Specific Gravity, Air = 1. By Calculation.	Specific Gravity, Air = 1. By Experiment.	Authority.
1. Cohesive Combinations.								
1. Carbonic Oxide . .	C + O	12 + 16	28	2	14	·972	·973	Thenard.
2. Nitric Oxide . . .	N + O	14 + 16	30	2	15	1·041	1·037	Do.
3. Muriatic Acid . .	Cl + H	36 + 1	37	2	$18\frac{1}{2}$	1·284	1·248	Biot & Arago.
4. Hydrobromic Acid .	Br + H	80 + 1	81	2	$40\frac{1}{2}$	2·812	2·731	Turner.
5. Hydriodic Acid . .	I + H	126 + 1	127	2	$63\frac{1}{2}$	4·409	4·443	Gay Lussac.
6. Bisulphuret of Mercury	S + 2 M	32 + 200	232	3	$77\frac{1}{3}$	5·370	5·384	Dumas.
7. Common Air	O + 4 N	16 + 56	72	5	$14\frac{2}{5}$	1·	1·	Assumed.
2. Combinations in Single Groups.								
8. Cyanogen . . .	N + C	14 + 12	26	1	26	1·805	1·806	Gay Lussac.
9. Dichloride of Sulphur	S + Cl	32 + 36	68	1	68	4·722	4·70	Dumas.
10. Fluoboric Acid . .	F + B	18 + 16	34	1	34	2·361	2·360	Davy.
11. Biniodide of Mercury	I + Hg	126 + 100	226	1	226	15·694	15·670	Mitscherlich.
12 Bichloride of Mercury	Cl + Hg	36 + 100	136	1	136	9·444	9·440	Do.
13. Bibromide of Mercury	Br + Hg	80 + 100	180	1	180	12·50	12·36	Do.
14. Olefiant Gas . . .	C + 2 H	12 + 2	14	1	14	·972	·978	Henry.
15. Fluosilicic Acid .	Si + 2 F	16 + 36	52	1	52	3·611	3·60	Thompson.
16. Chloride of Silicon	Si + 2 Cl	16 + 72	88	1	88	6·111	5·939	Dumas.
17. Nitrous Acid . .	N + 2 O	14 + 32	46	1	46	3·194	3·177	Gay Lussac.
18. Hydrocarburet of Chlorine . .	Cl + (C + 2 H)	36 + 14	50	1	50	3·472	3·443	Do.
19. Ætherine . . .	2 C + 4 H	24 + 4	28	1	28	1·944	1·91	Faraday.
20. Bicarburet of Hydrogen . . .	3 C + 3 H	36 + 3	39	1	39	2·708	2·776	Do.
21. Naphtha	3 C + 5 H	36 + 5	41	1	41	2·847	2·833	Saussure.
22. Naphthaline . . .	5 C + 4 H	60 + 4	64	1	64	4·444	4·528	Dumas.
23. Camphene . . .	5 C + 8 H	60 + 8	68	1	68	4·722	4·767	Do.
24. Oil of Turpentine .	6 C + 8 H	72 + 8	80	1	80	5·555	5·013	Gay Lussac.
25. Arsenious Acid . .	4 As + 3 O	152 + 48	200	1	200	13·888	13·67	Dumas.

3. Combinations in Double Groups.

Name.	Nos. and Weights of Elements.		Wt. of Atom.	Vol.	Sp. Gr. Hy. = 1.	Specific Gravity, Air=1. By Calculation.	Specific Gravity, Air=1. By Experiment.	Authority.
26. Water	O + 2 H	16 + 2	18	2	9	·625	·628	Gay Lussac.
27. Sulphuretted Hydrogen . . .	S + 2 H	32 + 2	34	2	17	1·180	1·190	Thenard.
28. Carbonic Acid . .	C + 2 O	12 + 32	44	2	22	1·527	1·519	Do.
29. Sulphurous Acid .	S + 2 O	32 + 32	64	2	32	2·222	2·255	Berzelius.
30. Chloride of Sulphur	S + 2 Cl	32 + 72	104	2	52	3·611	3·67	Dumas.
31. Nitrous Oxide . .	O + 2 N	16 + 28	44	2	22	1·527	1·522	Thenard.
32. Bisulphuret of Carbon	C + 2 S	12 + 64	76	2	38	2·638	2·644	Gay Lussac.
33. Borochloric Acid .	B + 2 Cl	16 + 72	88	2	44	3·055	3·942	Dumas.
34. Deutoxide of Chlorine	Cl + 2 O	36 + 32	68	2	34	2·361	2·346	Thenard.
35. Protochloride of Mercury . .	Cl + 2 Hg	36 + 200	236	2	118	8·194	8·20	Mitscherlich.
36. Bromide of Mercury	Br + 2 Hg	80 + 200	280	2	140	9·722	9·665	Do.
37. Hydrocyanic Acid .	H + (N + C)	1 + 26	27	2	13½	·937	·947	Gay Lussac.
38. Chlorocyanic Acid .	Cl + (N + C)	36 + 26	62	2	31	2·152	2·153	Dumas.
39. Ammonia . . .	N + 3 H	14 + 3	17	2	8½	·590	·597	Biot & Arago.
40. Sulphuric Acid . .	S + 3 O	32 + 48	80	2	40	2·777	3·00	Mitscherlich.
41. Inflammable Gas of Dr. Thompson	(C+2H)3+Cl	14 + 108	122	2	61	4·236	4·175	Thompson.
42. Phosphuretted Hydrogen . . .	2 P + 3 H	32 + 3	35	2	17½	1·215	1·214	Dumas.
43. Arsenuretted Hydrogen . . .	2 As + 3 H	76 + 3	79	2	39½	2·743	2·695	Do.
44. Chloride of Phosphorus . . .	2 P + 3 Cl	32 + 108	140	2	70	4·861	4·875	Do.
45. Chloride of Arsenic	2 As + 3 Cl	76 + 108	184	2	92	6·388	6·30	Do.
46. Perchloride of Tin .	Tn + 4 Cl	116 + 144	260	2	130	9·027	9·199	Do.
47. Light Carburetted Hydrogen . .	C + 4 H	12 + 4	16	2	8	·555	·559	Henry.
48. Perchloride of Titanium	Ti + 4 H	52 + 144	196	2	98	6·805	6·856	Dumas.
49. Perphosphuretted Hydrogen . .	3 P + 3 H	48 + 3	51	2	25½	1·770	1·761	Do.
50. Alcohol	O + 2 C + 6 H	16 + 24 + 6	46	2	23	1·597	1·613	Gay Lussac.
51. Oil Gas	3 C + 6 H	36 + 6	42	2	21	1·458	1·458	Henry.
52. Æther	O+4 C+10 H	16 + 48 + 10	74	2	37	2·569	2·586	Gay Lussac.
53. Muriatic Æther. .	Cl+2 C + 5 H	36 + 24 + 5	65	2	32½	2·256	2·219	Thenard.
54. Hydriodic Æther .	T+ 2 C + 5 H	126 + 24 + 5	155	2	77½	5·381	5·474	Gay Lussac.
55. Citrene	5 C + 8 H	60 + 8	68	2	34	2·361	2·383	Dumas.
56. Paranaphhaline .	15 C + 12 H	180 + 12	192	2	96	6·666	6·741	Do.
57. Chloro-carbonic Acid	2 Cl + (O+C)	72 + 28	100	2	50	3·472	3·472	Henry.

On Gaseous Interference. By Dr. Charles Henry.

It is universally known to chemists, that if oxygen and hydrogen be mixed, and brought into contact with metallic platinum in the state of wire or foil, or more especially in the spongy form, the combi-

nation of these gases is very rapidly achieved, and if mixed in the proper proportion, they are converted, usually with the phænomena of ignition, altogether into water. It is also well known, and was first noticed by Dr. Turner, that if into an atmosphere of oxygen and hydrogen, mixed in the ratio necessary for forming water, certain other inflammable gases, such as carbonic oxide and olefiant gas be introduced, the combination of the oxygen and hydrogen is, if not altogether suspended, at least materially interrupted. This is what Dr. Henry denominates *gaseous interference*. The cause of this remarkable effect has, at different times, attracted the attention of eminent chemists. Dr. Turner has ascribed it to the soiling of the platinum by the interfering gas; Dr. Faraday to some peculiar condition induced in the metal; while Dr. Henry himself, at a period long prior to the present, conceived it to arise from the fact of carbonic oxide and olefiant gas having a stronger affinity than hydrogen for oxygen gas. In his present paper, Dr. Henry investigated the entire question. The prominent facts and inferences appeared to be that carbonic oxide retards and limits, but does not altogether prevent the action of platinum on the usual explosive mixture, and the same may be said of olefiant gas. The *interfering* power, however, of the former is vastly greater than that of the latter, their ratio being represented by the numbers 18 and 1. In the case of carbonic oxide, carbonic acid is always produced, the amount depending on the form of the platinum employed, the quantity of the interfering gas, and the temperature at which the experiment is conducted; and, as a general rule, it may be laid down, that the interfering influence of the gas bears an inverse relation to the energy with which the platinum acts, and the degree of heat—conditions, however, which may be considered as identical. The diminution, and even disappearance, of interference at high temperatures, Dr. Henry attributes to a relative augmentation of the affinity of hydrogen for oxygen, an hypothesis indeed established by other and independent facts.

That Dr. Henry's theory of gaseous interference is the true one, he infers from the general fact of no gases exercising any such influence but those which have an affinity for oxygen; and that it is strictly true, at least in the case of carbonic oxide, there can be no question, seeing that some of the oxygen is actually employed in the production of carbonic acid.

In the course of the paper several other interesting facts, of a collateral description, were stated, and, amongst others, that platinum causes, though slowly, the combination of a mixture of oxygen and carbonic oxide, but that the process is facilitated by the introduction into the jar of a little caustic potash. This latter circumstance he attributed to the removal of the carbonic acid by the potash as fast as it was produced.

Experiments on the Combinations of Sulphuric Acid and Water. By THOMAS THOMSON, *M.D., F.R.S.L. and E., &c., Professor of Chemistry in the University of Glasgow.*

To obtain pure sulphuric acid, Nordhausen acid diluted with water till its specific gravity was only 1·8375 was distilled in a retort till the liquid remaining in the retort was precisely the same with that of the last portion distilled over. This happened when the specific gravity of the acid was 1·8422. It was then a compound of

1 atom acid	5
1 atom water	1·125
	6·125

and its atomic weight 6·125. This acid, which was pure, (excepting the presence of $\frac{1}{3000}$th part of its weight of sulphate of lime) was employed in the following experiment:

1. *Specific gravity of different atomic compounds of sulphuric acid and water.*

These were obtained by mixing determinate weights of acid and water, and taking the specific gravity of the compound. The following table shows the result:

Acid.	Water.	By Experiment.	By Calculation.	Difference.
1 Atom	+ 1 Atom	1·8422		
,,	+ 2 ,,	1·7837	1·7114	+ 0·0723 or $\frac{1}{24\frac{2}{3}}$
,,	+ 3 ,,	1·6588	1·6158	+ 0·0430 or $\frac{1}{38\cdot5}$
,,	+ 4 ,,	1·5593	1·5429	+ 0·0164 or $\frac{1}{95}$
,,	+ 5 ,,	1·4737	1·4854	− 0·0117 or $\frac{1}{127}$
,,	+ 6 ,,	1·4170	1·4389	− 0·0219 or $\frac{1}{65\cdot7}$
,,	+ 7 ,,	1·3730	1·4006	− 0·0276 or $\frac{1}{50\cdot7}$
,,	+ 8 ,,	1·3417	1·3684	− 0·0267 or $\frac{1}{51\cdot2}$
,,	+ 9 ,,	1·5105	1·3410	− 0·0305 or $\frac{1}{43\cdot9}$
,,	+ 10 ,,	1·2845	1·3174	− 0·0329 or $\frac{1}{40}$

From this table we see that the compound of one atom oil of vitriol, with one, two, and three atoms water, has a specific gravity above the mean, while the compounds of one atom oil of vitriol, with four, five, six, seven, eight, and nine atoms water, are below the mean. In the first case there is a condensation, but in the second an expansion, and this expansion increases with the quantity of water.

2. *Heat evolved when an atom of oil of vitriol is mixed with from one to nine atoms water.*

This was determined by pouring 1000 grains of oil of vitriol of 1·8422, upon the requisite quantity of water in a glass cylinder containing the water, and stirring the mixture with a thermometer. The thermometer rises with very great rapidity, and begins almost immediately to descend, so that it is difficult to notice the highest point to which it rises. The following table shows the result.

Oil of Vitriol.	Water.	Weight of Acid.	Weight of Water.	Thermometer rose from	Heat evolved.
		Grains.	Grains.		
1 Atom +	1 Atom	1000	183·6	60° to 245°	185°
,,	2 ,,	1000	367·3	67 to 286	219
,,	3 ,,	1000	550·9	60 to 268	208
,,	4 ,,	1000	734·6	60 to 263	203
,,	5 ,,	1000	918·3	60 to 238	178
,,	6 ,,	1000	1102	59 to 222	163
,,	7 ,,	1000	1285·7	59 to 207	148
,,	8 ,,	1000	1469·3	59 to 198	139
,,	9 ,,	1000	1653	59 to 188	129

But when oil of vitriol previously mixed with water in atomic proportions is mixed with an atom of water, the heat evolved is much less. This will appear from the following table.

Acid.	Water.	Water.	Thermometer rose from	Heat evolved.
(1 Atom	+ 1 Atom)	+ 1 Atom	60° to 245°	185°
(1 ,,	+ 2 ,,)	+ 1 ,,	65 to 135	70
(1 ,,	+ 3 ,,)	+ 1 ,,	64 to 110	46
(1 ,,	+ 4 ,,)	+ 1 ,,	60 to 95	35
(1 ,,	+ 5 ,,)	+ 1 ,,	63 to 76	13
(1 ,,	+ 6 ,,)	+ 1 ,,	63 to 72	9
(1 ,,	+ 7 ,,)	+ 1 ,,	63 to 70	7
(1 ,,	+ 8 ,,)	+ 1 ,,	63 to 69	6
(1 ,,	+ 9 ,,)	+ 1 ,,	63 to 67	4

3. *Specific heats of various atomic compounds of sulphuric acid and water.*

This was determined by putting 24 cubic inches of the acids to be tried in a flask, heating them 80° above the air of the room, and noting the number of seconds which each took to cool 40°. The following table shows the result.

Time of Cooling, 40°.	
Empty flasks	215″·5
24 Inches of Water	5720″·7
1 Atom Acid + 1 Atom Water	5860
,, + 2 ,,	4837·7
,, + 3 ,,	4587·2
,, + 4 ,,	4702·7
,, + 5 ,,	4831·7
,, + 6 ,,	4967·3
,, + 7 ,,	5075
,, + 8 ,,	5169·3
,, + 9 ,,	5267·7
,, + 10 ,,	5307·5

By subtracting the 215″·5 (the time the empty flasks took to cool) from the numbers in the preceding table, we obtained the ratios of the specific heat of equal volumes of the above mixtures. By dividing these numbers by the specific gravities of the various liquids as given above, we obtain the specific heats of equal weights of each. The following table shows these specific heats, that of water being reckoned unity.

	Sp. Heats.
Water	1·0000
1 Acid + 1 Water	0·3593
,, + 2 ,,	0·4707
,, + 3 ,,	0·4786
,, + 4 ,,	0·5228
,, + 5 ,,	0·5690
,, + 6 ,,	0·6091
,, + 7 ,,	0·6429
,, + 8 ,,	0·6699
,, + 9 ,,	0·7003
,, + 10 ,,	0·7201

To know how far these numbers accord with the theory of Dr. Irvine, at present universally admitted, namely, that the heat evolved when oil of vitriol and water are mixed is owing to the diminution of the specific heat, we must make a comparison of the specific heats above found with the specific heat of the mixture, supposing it a mean of the specific heats of the acid and water without any change. This is done in the following table.

	Sp. Heat by Exp.	Mean Sp. Heats.	Differences.
Water..........	1·0000		
Acid. Water. 1 Atom + 1 Atom	0·3593		
,, + 2 ,,	0·4707	0·4587	+ 0·0120
,, + 3 ,,	0·4786	0·5326	− 0·0540
,, + 4 ,,	0·5228	0·5869	− 0·0641
,, + 5 ,,	0·5690	0·6306	− 0·0616
,, + 6 ,,	0·6091	0·6660	− 0·0569
,, + 7 ,,	0·6428	0·6952	− 0·0524
,, + 8 ,,	0·6699	0·7197	− 0·0498
,, + 9 ,,	0·7003	0·7405	− 0·0402
,, + 10 ,,	0·7201	0·7585	− 0·0384

The slightest comparison of the second and third columns of the table is sufficient to show that the theory of Dr. Irvine cannot be accurate. The specific heat of a compound of 1 atom oil of vitriol and

1 atom water is greater than the mean by about $\frac{1}{40}$th. Hence it is impossible that the heat evolved can be a consequence of a diminution, when no such diminution exists. In all the other compounds there is a diminution of the specific heat, but it does not correspond with the heat evolved. The greatest takes place when one atom of oil of vitriol is mixed with three atoms water. It amounts, in that case, to about $\frac{1}{9}$th, and the heat evolved is 208°. But when one atom of oil of vitriol is mixed with two atoms of water, the heat evolved is 219°; yet the diminution of specific heat is only about $\frac{1}{10}$, and consequently less than when the heat evolved is only 208°. The same want of coincidence exists in every part of the table. Hence it follows, that when oil of vitriol and water are mixed the heat evolved is not the consequence of a diminution of the specific heat.

Dulong and Petit observed that when the atomic weight of a simple body is multiplied by its specific heat the product is a constant quantity. Dr. Thompson has shown in a paper published in the third volume of the *Records of General Science*, that this constant quantity is 0·375. It follows from this law, that the same absolute quantity of heat exists in combination with every simple atom; that the differences of the specific heats of different simple bodies are owing to a difference in their atomic weights.

In the same paper it is shown that when the atomic weight of a compound body is multiplied by its specific heat, the product is always a multiple of 0·375 by a whole number, which number depends upon, or at least is connected with the number of atoms of which the compound body is composed. If the number multiplying 0·375 be equal to the number of atoms in the compound body, then it follows that every atom of the compound body retains all the heat with which it was combined when in an isolated state. If the multiple be less than the number of atoms, then the compound contains less heat than existed in its elements, and the difference between the multiple and the number of atoms gives us the proportion of heat wanting.

Let us apply this method to the combinations of oil of vitriol and water. The following table exhibits the result.

	Atomic weight.	Specific heat.	Product of cols. 2 & 3.	
Water	1·125	1·0000	1·125	= 0·375 × 3
1 Acid + 1 Water	6·125	0·3593	2·201	= × 5·87
„ + 2 „	7·25	0·4707	3·412	= × 9·09
„ + 3 „	8·375	0·4786	4·008	= × 10·68
„ + 4 „	9·5	0·5228	4·966	= × 13·24
„ + 5 „	10·625	0·5690	6·046	= × 16·12
„ + 6 „	11·75	0·6091	7·157	= × 19·08
„ + 7 „	12·875	0·6429	8·277	= × 22·07
„ + 8 „	14	0·6699	9·379	= × 25·01
„ + 9 „	15·125	0·7003	10·592	= × 28·24
„ + 10 „	16·25	0·7201	11·702	= × 31·20

The last column shows to what number multiplied by 0·375, the product of the atomic weight by the specific heat is equal. These numbers approximate to 3, 6, 9, 11, 13, 16, 19, 22, 25, 28, and 31; and Dr. Thompson thinks it probable that if the experiments on the specific heat of these compounds had been perfectly accurate, there would have been the exact numbers, which, multiplied by 0·375, would have represented the product of the atomic weight into the specific heat.

Now, sulphuric acid is a compound of one atom sulphur and three atoms oxygen, so that an integrant particle of it contains four atoms. British chemists, in general, consider water as a compound of one atom oxygen and one atom hydrogen; but the continental chemists consider it as a compound of one atom oxygen and two atoms hydrogen, considering the number of volumes as measuring the number of atoms. Many unanswerable reasons might be given for adopting this last conclusion as the true one. If, then, we admit that sulphuric acid contains four atoms, and water three atoms, we may compare the number of atoms in each compound with the multipliers of 0·375, which represent the product of the atomic weight of each into its specific heat. This is done in the following table.

	Number of atoms.	Multipl. of 0·375.	Difference.	Heat evolved.
Water..........	3	3	0	
1 Acid + 1 Water	7	6	1	185°
,, + 2 ,,	10	9	1	70
,, + 3 ,,	13	11	2	46
,, + 4 ,,	16	13	3	35
,, + 5 ,,	19	16	3	13
,, + 6 ,,	22	19	3	9
,, + 7 ,,	25	22	3	7
,, + 8 ,,	28	25	3	6
,, + 9 ,,	31	28	3	4
,, + 10 ,,	34	31	3	

From this table it is evident that when an integrant particle of oil of vitriol is combined with an integrant particle of water, the specific heat of the compound, instead of being $0{\cdot}375 \times 7$, is only $0{\cdot}375 \times 6$; so that $\frac{1}{7}$th of the whole heat is thrown out. This amounts to 185°. We see from this the cause of the evolution of heat, and we see at the same time that the whole heat which existed in the water and oil of vitriol before combination was $185 \times 7 = 1295°$.

When an integrant particle of acid, composed of (1 acid + 2 water) is mixed with a particle of water, the heat of the compound is less than $0{\cdot}375 \times 13$, by $0{\cdot}375 \times 2$. In this case $\frac{2}{13}$ths of the heat are evolved. When an integrant particle of acid composed of (1 acid + 3 water) is mixed with a particle of water, the heat of the compound, instead of being $0{\cdot}375 \times 16$, is only $0{\cdot}375 \times 13$, or $\frac{3}{16}$ths of the heat are evolved.

From these examples the cause of the evolution of heat is evident, and we have a method of determining the absolute quantity of heat in bodies, which has been so long a desideratum.

On a Method of Ascertaining the Strength of Spirits. By Wm. Black.

The author believes it has long been a desideratum with Government to find a more scientific and accurate mode of trying the strength of spirits than that now in use. A very slight inattention in the mode of using the hydrometer may make a difference of at least five per cent.; and when the spirits are adulterated with sugar or salts that instrument is totally useless.

It is generally known that when equal quantities of proof spirits and water are mixed together at equal temperatures between 50° and 60° Fahrenheit, the thermometer will, if immediately immersed in the mixture, rise $9\frac{1}{2}$ degrees, half a degree of caloric being perhaps absorbed by the instrument in making the experiment.

Mr. Black however thinks it is not so generally known that the thermometer rises more or less according to the strength of the spirits, and that it does so apparently in very regular progression. When spirits 45 per cent. over proof are mixed in equal quantities with water, both being at the same temperature, between 50° and 60°, the thermometer, if immediately immersed in the mixture, will rise 14 degrees; but with the strongest alcohol, also mixed in equal quantities with water, it will not rise above that temperature unless more water be added, showing that no further concentration takes place, and that the alcohol can only combine with the water in fixed proportions, and that a certain portion of the spirit must remain in the first mixture in an uncombined state. Every degree on the thermometer appears to indicate a difference of 10 per cent. in the strength of the spirit. Thus, if we mix equal quantities of spirit, 10 per cent. over proof, and water, both at equal temperatures of about 55°, the thermometer will rise $10\frac{1}{2}$°; with spirits 20 o.p. it will rise $11\frac{1}{2}$°; and so on, one degree for every additional 10 per cent. o.p. until it reaches 40 or 45 o.p., when no further increase is apparent, unless, as before stated, more water be added.

The thermometer seems to act in a similar manner with spirits under proof; thus with spirits 10 per cent. u.p. mixed with water as above the indication is $8\frac{1}{2}$°, and one degree less for every 10 per cent. under until we get to 45 per cent. u.p., after which, although a rise does take place, Mr. Black is not sure that the indications are so regular.

When spirits are mixed with sugar, thus increasing the specific gravity so as to falsify the hydrometer 20 or 30 per cent or more, the indications of the thermometer are precisely the same, if we make allowance for the slight difference in volume caused by the mixture of sugar.

If the mixtures be made at higher temperatures the thermometer indicates a lesser number of degrees in rise according to the temperatures.

When between 70° and 80°, nearly two degrees less; but the progressions appear to go on regularly as before. The thermometer also gives pretty accurate results with wine or strong beer when applied as above.

The author does not however presume to give the above as accurate results, but merely to state that the thermometer appears to indicate a regular progression according to the strength of the spirits and the temperatures at which the experiments may be made. He desires at present to draw attention to the subject, in hopes that some mode of application may be discovered which may render it available, and perhaps accurate, in ascertaining the qualities of spirits or acids.

Notice of a new Gaseous Bicarburet of Hydrogen. By EDMUND DAVY, *F.R.S., M.R.I.A., &c., Professor of Chemistry to the Royal Dublin Society.*

Early in the present year the author, in attempting to procure potassium by strongly heating a mixture of calcined tartar and charcoal in a large iron bottle, obtained a black substance, which readily decomposed water, and yielded a gas which on examination proved to be a new compound of carbon and hydrogen. This gas is highly inflammable, and when kindled in contact with air burns with a bright flame, apparently denser and of greater splendour than even olefiant gas. If the supply of air is limited the combustion of the gas is accompanied with a copious deposition of carbon. When the new gas is brought in contact with chlorine gas instant explosion takes place, accompanied by a large red flame and the deposition of much carbon; and these effects readily take place in the dark, and are of course quite independent of the action of the sun's rays or of light.

The new gas may be kept over mercury for an indefinite time without undergoing any apparent change, but it is slowly absorbed by water. Distilled water recently boiled, when agitated in contact with the new gas, absorbs about its own volume of it; but on heating the aqueous solution the gas is evolved apparently unaltered. The new gas is absorbed to a certain extent by, and blackens, sulphuric acid. It detonates powerfully when mixed with oxygen gas, especially if the latter forms three fourths or more of the mixture; and the only products of its combustion with oxygen are carbonic acid gas and water.

The new gas requires for its complete combustion two and half volumes of oxygen gas, which are converted into volumes of carbonic acid gas and water.

From the author's analysis of the new gas by different methods, it appears to be composed of one volume of hydrogen, and two volumes of the vapour of carbon condensed into one volume. Hence the new gas contains as much carbon, but only half the quantity of hydrogen, that is in olefiant gas. The density of the former is therefore less than that of the latter, by the weight of a volume of hydrogen equal to its own bulk. The new gas is in fact a *bicarburet of hydrogen*, composed of

two proportions of carbon and one of hydrogen, and may be represented by the formula $C^2 + H^1$ or $2\,C + H$, and differs in constitution, the author presumes, from that of any other known compound of carbon and hydrogen.

From the brilliancy with which the new gas burns in contact with the atmosphere, it is, in the opinion of the author, admirably adapted for the purposes of artificial light if it can be procured at a cheap rate.

A more detailed account of the properties and relations of the new gas, and of the experiments on which the foregoing statements are founded, probably will shortly appear either in the Transactions of the Royal Dublin Society or of the Royal Irish Academy.

Professor Davy made the new gas, and illustrated some of its most striking properties, at the Scientific Meeting of the Royal Dublin Society last March.

Notice of a peculiar Compound of Carbon and Potassium, or Carburet of Potassium, &c. By EDMUND DAVY, *F.R.S., M.R.I.A., &c., Professor of Chemistry to the Royal Dublin Society.*

In January last the author made different experiments to obtain the metal of potash on a large scale, by exposing to a high temperature in an iron bottle a mixture of previously ignited tartar and charcoal powder, in proportions of the latter varying from about $\frac{1}{10}$ to $\frac{1}{15}$ of the whole mass. In one experiment a substance was obtained of a dark grey colour, rather soft to the knife, though adhering with great tenacity to the iron and inclining to a granular structure. This substance, when thrown into water, decomposes it with great facility, carbonaceous matter is disengaged and gas copiously evolved, with occasional inflammations on the surface, as is commonly the case with potassium under similar circumstances. The gas when examined was found to consist of hydrogen, and the new compound of carbon and hydrogen (noticed in a separate communication), in nearly equal volumes. The author regards this substance as a mixture of potassium and carburet of potassium; the former by its action on water furnishing the hydrogen, and the latter the new gas. In collecting gas from this substance by the action of water over mercury a novel and interesting case of combustion was observed. A little of the substance being placed at the end of a tube filled with mercury, on letting up a few drops of water gas was copiously disengaged, and as the mercury descended along the tube small portions of the substance became ignited, exhibiting the appearance of bright sparks of fire in continual succession.

In another experiment with the iron bottle no potassium was obtained, but a small quantity of a substance partly in powder and partly in small lumps of a dense black colour, which the author considers carburet of potassium, probably in a purer state than has yet been described.

This carburet exhibits no appearance of crystallization to the naked eye, but when viewed with a glass of high magnifying power the au-

thor thinks he has observed congeries of exceedingly minute four-sided prisms truncated at their solid angles.

When a small portion of the carburet is exposed to the air it soon undergoes changes, oxygen is absorbed, and water, and the damp substance has a burning taste and is caustic potash with carbon.

When the carburet is put into water both substances are decomposed: one portion of the carbon unites with the hydrogen of the water forming the new bicarburet of hydrogen, which seems the only gaseous product, the remaining carbon being disengaged, whilst the oxygen of the water and the potassium form potash. Alcohol and turpentine act very feebly on the carburet, acids strongly.

The carburet undergoes partial decomposition at a dull red heat in close vessels, potassium slowly rises from it, whilst the carbon remains of a deeper black colour than the carburet.

From the author's experiments the carburet appears to be composed of one proportion of carbon and one of potassium.

Mr. Mushet exhibited to the Chemical Section several pieces of iron ore retaining their original structural form, but converted into masses of malleable iron perfectly ductile and capable of receiving polish. He explained to the section that this curious change was effected by a protracted process of de-oxydation in contact with carbonaceous matter shut up from all access of atmospheric air,—the temperature of the furnace about 80 of Wedgwood according to the old method of reckoning, this limitation of temperature being necessary to produce the effects. With a higher temperature a more powerful affinity would be established between the particles of iron and the embedding carbonaceous matter, which in the first instance would convert the masses into steel; and next, by superinducing fusion, into cast iron more or less a carburet, according to the proportion of carbon which may have united with the iron. The pieces of iron ore may, by being presented to fresh charcoal under a repetition of the process, be converted into steel, preserving as in the present specimen their original forms altogether unchanged. One of the pieces had by de-oxydation for twelve or fourteen days passed into the state of steel; the others in the state of malleable iron had been exposed for about a week. Mr. M. then stated that the specimens exhibited were made from the hydrous oxide of iron known in the Forest of Dean by the name of Black Brush, but that other ores, and even the peroxides of Lancashire and Cumberland, were subject to the same change by following the same line of operation. The converted ore contained 95 per cent. of malleable iron, a portion of which if melted alone would be re-oxydized so far as to produce only 70 per cent. of cast malleable iron,—the waste or deficient iron being found in the state of a metallic shining glass covering the surface of the precipitated iron; but if melted with $\frac{1}{40}$th its weight of charcoal, 96 per cent. of good cast steel will be the result; and with $\frac{1}{12}$th or $\frac{1}{15}$th the weight of the ore of charcoal, 98 per cent. of the richest

quality of cast iron. In the last two operations the small quantity of earthy matter in the ore will appear in the form of a clear glass with a slight purple tinge.

Mr. Mushet described the process of smelting iron ores in the blast furnace as of a twofold nature, and stated that it exhibited all the phænomena now alluded to (namely de-oxydation and carburation); crude or cast iron when run from the blast furnace must have passed through the various stages of malleable iron and steel before absorbing as much carbon from the fuel as would enable the iron to flow from the furnace. In the upper region of the blast furnace the first operation that takes place towards a perfect reduction is the gradual de-oxydation of the iron ore by the heated fuel in the absence, or nearly so, of oxygen. When this is perfected the particles are in the state of soft or malleable iron, but owing to the short time they are exposed, and the inferior temperature, they are not welded together as in the specimens which were exhibited. As the ore, however, descends in the furnace and meets with a higher temperature and an enlarged volume of fuel, an affinity is established between it and the particles of iron, which by absorbing about $\frac{1}{60}$th of their weight pass into the steely state. A further descent in the furnace towards its greatest diameter brings the iron in the state of crude steel into a still higher temperature and in contact with a larger body of fuel, in consequence of which a more powerful affinity is exerted, and the iron finally separated in the state of cast iron, more or less a carburet as the purposes of the manufacturer may require.

In reference to the protracted process of de-oxydation first alluded to, Mr. Muschet stated that a higher temperature, although required to weld and compact together the particles of iron, was not necessary for the de-oxydation itself, for at a bright red heat all but the very last portions of oxygen may be attracted from the iron, and the pieces of ore left easy to be pulverized. He had at one time taken advantage of this circumstance to form from the iron ore a powerful metallic cement calculated to give stability to great national undertakings, such as the Plymouth Breakwater, Lighthouses, &c. He presented specimens of it resembling masses of iron at a meeting of the Society of Civil Engineers, with which that intelligent body (the late Mr. Telford then at their head) expressed themselves highly pleased. But without reference to its merits, as soon as it was known that it could not be rendered as cheap as Roman cement, it ceased to excite any interest and was never inquired after. Sir John Rennie however saw its value, and was anxious to introduce it at the Plymouth Breakwater and at other places, and took a great deal of trouble in the matter. Three or four casks were sent to the Breakwater and there misapplied, as an unfavourable report reached the Admiralty sometime afterwards. This singular cement differs from all others, inasmuch as it expands in the act of setting, by which means it never shrinks from the substance to which it is attached, but becomes completely united with it. The West India Dock Company alone seem to appreciate its peculiar properties. They find that it binds together their granite pavement in a way superior to everything else. (The manufacture of it has been discontinued).

On the Conducting Powers of Iodine. *By* JAMES INGLIS, *M.D.*

The author in this communication replies to objections which had been raised relative to the assertion contained in his Prize Essay on iodine, viz., that this substance is a conductor of electricity. In the experiments which he instituted for the purpose he employed iodine from the manufactory of Mr. Whitelaw of Glasgow, where no iron vessel is ever employed, and in which in its veriest impurity no iron can be detected. He exhibited a tube containing an aqueous solution of ioduret of iron, a second containing an aqueous solution of the iodine to be tested, and a third having in it a solution of the ferrocyanate of potass. Now, on adding a portion of the last to the iron solution, immediately the blue ferrocyanate of iron is formed, but no such effect takes place when added to the solution of iodine. Add, however, now a single drop of the ioduret solution and instantly the blue precipitate falls.

But supposing that a small portion of the ioduret was present, we know that from its great affinity for water it could be removed by washing. Being therefore washed, thoroughly dried with blotting paper, and lastly sublimed three times, it is presumed the iodine used was as pure as possible.

Having put a portion of this into a tube with a platinum wire hermetically sealed into one extremity, a second wire was introduced at the other, till one end approached the former to within about the fourth of an inch; this extremity was now hermetically sealed; so that the arrangement consisted in a closed tube containing perfectly dry and pure iodine, with two separate platinum wires communicating together only through the medium of the iodine. A galvanic trough was now charged, and one of the platinum wires attached to the positive pole, whilst the other was placed in a glass of acidulated water; on forming the galvanic circle no effect was produced, nor was there any difference on reversing the poles.

The iodine being now liquified by the flame of a spirit lamp, and the tube attached to the negative pole, the platinum wire was placed as before in water, and on completing the circle by a copper wire from the positive pole, instantly bubbles of gas appeared, and were evolved at the platinum wire, whilst none appeared at the copper, being positive.

The order being reversed, evolution took place at both wires, proving clearly that decomposition had been effected. Again, on placing the wire on the tongue, and touching the other pole, a strong galvanic sensation is instantly experienced. On removing the heat the power of conducting gradually dies away, so that in seven minutes it is incapable of transmitting even sufficient to be felt by the tongue. Therefore Dr. Inglis, when he stated in a note attached to Mr. Solly's paper that iodine when cold and concrete still conducted, was in error, being led to say so from recollection only. But his general statement *that iodine was a conductor* is satisfactorily shown to be borne out by experiment.

On Paracyanogen, a new Isomeric Compound. By J. F. W. JOHNSTON, *A.M., Professor of Chemistry, Durham.*

When protocyanide of mercury is heated, cyanogen is given off and a black substance remains. When the salt is perfectly dry, the gas given off is altogether absorbed by potash, and is perfectly pure. Professor Johnston therefore concluded that the residual black substance was isomeric with cyanogen. Having communicated this view to M. Liebig, an accurate analysis by that chemist confirmed its truth. Professor Johnston described the principal properties of this remarkable body, which is a very stable compound, but is converted into cyanogen by an elevated temperature, or by heating it with potassium, with which it forms the ordinary cyanide.

On Arsenical Poisons. By W. HERAPATH.

As arsenical poisons are obtained with much facility and their operation is deadly, they are the principal means resorted to by the secret poisoner. It becomes, therefore, essential to the community that every new fact relating to their administration, operation, or detection should be made known. The author is not aware that any well-authenticated case of poisoning by red arsenic had been published till the Burdock case was examined. In this instance the victim, Mrs. Smith, had been buried fourteen months; upon examination *orpiment* was found in the stomach, and the body was partly converted into adipocire. In prosecuting his experiments Mr. Herapath conceived the idea of identifying the poison found with that sold by the druggist to the witness Evans through an impurity he discovered in the poison of the stomach. With this view he purchased some out of the same box, and requested that it might be of the same kind as that sold the prisoner's agent. It was then found that the box contained three different kinds of substances mixed together, white, yellow, and red arsenic, the two former in lumps, the latter in powder, and that it was the powder of *realgar* only which had been administered, although it was undoubtedly found as *yellow orpiment* in the exhumed body. In tracing the possibility of change, he found two agents, sulphuretted hydrogen and ammonia, which would convert realgar into orpiment. Now as it is well known that both of these gases are evolved during putrid decomposition, there could be no difficulty in accounting for the change of colour. But, to place the matter beyond all doubt, a direct experiment was made by poisoning an animal with realgar, which after putrefaction became changed, as in the case of Mrs. Smith. The conviction of the prisoner mainly rested on the evidence of a little girl, who deposed that she saw the prisoner Mrs. Burdock put a powder into some gruel and afterwards administer it to Mrs. Smith.

At the time considerable doubt was entertained of the truth of her evidence from its being invariably precise, even to a word, and also from the difficulty of believing that any person would be so fool-hardy as to mix and administer poison before a child, and that child a stranger.

But what she stated proves satisfactorily that her evidence was correct, for she said that "the gruel was of a nasty *red* colour," when nothing had transpired of red arsenic; and had she invented a tale to account for the appearance of the body, or had she spoken from what she heard from others, she would have said the gruel was of a yellow colour.

From what occurred, therefore, it is clear that the realgar of the shops would cause death; that half an ounce given at twice (by the prisoner's confession) was sufficient for that purpose; that realgar became orpiment during putrefaction; that realgar, like arsenious acid, had a tendency to control putrefaction, and convert bodies into adipocire.

During the experiments upon this case it was found that the microscopic system of testing, which was first introduced by Dr. Wollaston, and which Mr. Herapath constantly followed, could be made to improve the very beautiful reducing process proposed by Dr. Christison, and also furnished an excellent method of proving to the jury the presence of arsenic. The whole organic matter having been decomposed in boiling nitromuriatic acid, potash added in excess to prevent the injurious effects of mineral acids on sulphuretted hydrogen, a slight excess of acetic acid poured in, and the sulphuret of arsenic precipitated and reduced in Berzelius's tube to the metallic state, and then oxidized, as recommended by Christison, the author found in the subsequent experiments a modification of Dr. Wollaston's practice very beneficial.

Instead of putting the few drops of solution of arsenious acid thus obtained into test-tubes to apply the reagents, he used a china tablet, and having applied a drop of the solution, then a little ammoniacal sulphate of copper, the green of Scheele became evident by the contrast of colour with the white plate; but even that might be improved by guiding the coloured drop by means of a glass rod down upon a piece of white blotting paper, previously placed on a flat chalk-stone, which by absorbing the solution removed any excess of the blue reagent, (which which was always liable to overpower the colour of Scheele's green,) while it left the latter on the paper, and when dried it could be introduced into a sealed tube, which could be marked by a diamond, in the handwriting of the experimenter ready for identification before the jury. Mr. Herapath is satisfied that $\frac{1}{10000}$th of a grain of arsenious acid might be detected by these means. The other two reagents, ammoniacal nitrate of silver and sulphuretted hydrogen, can be applied in the same way, and when dried the product may be similarly inclosed. In all cases where a highly oxygenating process is followed, for instance, when the mixture is boiled in nitro-muriatic acid, or where deflagration with nitre is practised, the arsenical compound is converted into arsenic acid, and in passing sulphuretted hydrogen (after the usual precautions) the first portion of the gas is decomposed by giving hydrogen to the oxygen of the arsenic acid, consequently sulphur falls mixed with sulphuret of arsenic, but so extremely light that it takes some hours to deposit; after which the mixed mass may be collected together, and upon reducing it to metallic arsenic the sulphur would be separated; for from

being more volatile it is found above the crust of metal, and in the oxydizing process forms sulphurous acid and disappears, while the arsenious acid condenses.

It sometimes happens that arsenic is contained in substances which prevent the ordinary processes from being followed, for instance in the case of Sophia Edney, who was convicted at Taunton of poisoning her husband. The author found about an eighth of a grain in the duodenum (the contents of the stomach having been thrown away by the surgeon who examined the body, under the belief that an ulcer found in the stomach was sufficient to account for death); the only other matters brought for examination were a few grains of bacon-fat scraped from the edges of a frying-pan. In the fat he could find no arsenic, and the potatoe being an amylaceous substance, it was in vain to try the usual reagents or to make a filtered solution. It was therefore projected into melted nitre; when it was deflagrated, diluted acetic acid was added to rather more than neutralize the carbonate of potass resulting from the deflagration of the charcoal of the vegetable and animal substances. A stream of sulphuretted hydrogen was then passed through it, which turned it yellow, and upon deposition and subsequent treatment in the way alluded to before, enough was obtained to take to a jury: specimens of the reduced metal, of arsenious acid, Scheele's green, arsenite of silver and orpiment, although the reduced arsenic was not more than $\frac{1}{100}$ of a grain. It had been said by the dying man that his wife had fried potatoes in this pan for him and he had not been well since. The pan had been subsequently used to fry bacon, which had been eaten with impunity by two persons, exclusive of the prisoner, who had herself "eaten a bit as big as a nut;" yet there was enough left adhering to the pan to prove her guilt, which her confession subsequently acknowledged.

Although nitre affords an excellent means of removing all organic matter, and thus leaving the operator free from all embarrassment, yet it cannot be depended on in quantitative analysis, as a certain proportion is volatilized during the process; this loss might be reduced by putting a little nitre in the solution before evaporating to dryness.

The plan of discovering arsenious acid by arseniuretted hydrogen, and depositing the arsenious crust during its combustion, recently proposed by Mr. Marsh of Woolwich, was described by Mr. Herapath as the most elegant that could be conceived, and at the same time the most sensitive; he suggested the following precautions for the purpose of evidence before a jury. The zinc used for the preparation of hydrogen should have been treated by the experimenter in the same way without arsenic, or it might be supposed that the arsenic was contained in the zinc; the metallic crust should be so received as to be kept as much as possible from atmospheric air, otherwise it would lose its lustre by passing into the "Fly Powder" of the Germans.

Instead of a plate of glass to receive the crust Mr. H. used one of mica, with three drops of water in separate places on one of its surfaces; if the flame was allowed to play under one of those drops, the evaporation of the water kept the place cool, and the crust was thicker

while the risk of fracture was avoided. Then by inverting the plate, and holding the drops in succession some little height over the flame, they became solutions of arsenious acid, and could be tested with the three reagents as before stated. The part of the plate of mica containing the crust may then be cut off and introduced into glass tubes, hermetically sealed up like the slips of blotting paper containing the coloured results of the reagents. If it be necessary to make quantitative experiments, the products of the flame may be condensed in a large globe; the arsenious acid dissolved and precipitated by sulphuretted hydrogen.

On Lithiate of Ammonia as a Secretion of Insects. *By* WM. HERAPATH.

Lithic acid has been discovered as an abundant secretion in the urine of mammalia, in that of birds (particularly of those with carnivorous propensities), and in the excrement of the boa constrictor; but Mr. H. was not aware that it had been noticed among the insect tribes, previous to his examination of a fawn-coloured substance which is ejected with considerable force by the common silk-worm (*Phalæna Mori*) in its moth state of existence. This is principally composed of lithiate of ammonia. As the insects do not eat either in the chrysalis or the moth state, or even for some days before spinning, and as they discharge at the last-mentioned period all the remains of food and become transparent, it would seem that the lithiate of ammonia is not excrementitious in the common acceptation of the term, but a secretion destined for some particular purpose, possibly for softening the cocoon. He afterwards examined other insects of the moth tribe, and found that there are so many producing the same substance (varying a little in colour from the presence of rosacic or purpuric acids) that it might be considered as common to the tribe. Those who wish to carry on experiments upon this point will find good subjects in the privet hawk-moth (*Sphinx ligustri*), the lackey (*Neustria*), the puss moth (*Cerura vinula*), and the ermine.

It is remarkable that in the cases mentioned by Mr. Herapath the lithiate of ammonia should be produced by creatures living entirely on vegetable food.

Analysis of the Water of the King's Bath, Bath. *By* WM. HERAPATH.

	Grains.
On June 4th, 1836, the temperature of the spring head of the King's Bath while running was 114° F., and its sp. gr. at 60° was......................................	1·001905
Upon evaporating to dryness an imperial pint of 8750 grs. the residue was found to be..........................	19·075

A.—A little spirit of wine was three times affused upon this and decanted; it had dissolved 3·23 grs.; slow crystallization under the microscope showed it to be chloride of magnesium and chloride of sodium; there was no chloride of

	Grains.
calcium or strontium: precipitated by carbonate of ammonia and phosphate of soda the magnesia was equal to magnesium.	·187
The liquid acidulated with nitric acid, precipitated by nitrate silver, gave chloride of silver = chlorine	1·124
As ·187 magnesium is equal to ·560 chlorine, and the remaining ·564 chlorine to ·376 sodium, it follows that the loss was 1·543. As this loss was enormous it was supposed to be water of the muriate of magnesia; to prove which some magnesia was dissolved in muriatic acid, evaporated to dryness at the same heat, and found = 19·8 grs. while hot; decomposed by heat in a platina dish it weighed 7·45 only. This loss was equivalent to 1·428 on the muriate of magnesia of the spirituous solution, the difference between 1·543 and 1·428 being caused by inequality of heat or extractive matter.	
The spirit salts were therefore Chloride magnesium....	·747
Chloride sodium........	·940
Water................	1·543
B.—Acted on the remaining salts with water containing enough alcohol to prevent the solution of sulphate of lime; evaporated to dryness and re-dissolved in as little water as possible to leave behind any sulphate of lime which might yet have been dissolved; evaporation under the microscope showed the mass to be composed of the remainder of the common salt, sulphates of magnesia and soda. The magnesia was precipitated and found to be ·312 gr. After the addition of nitric acid to suspend the phosphates, nitrate of silver precipitated chloride equal to chlorine ·700. Then nitrate of barytes gave sulphate equal to sulphuric acid 1·360, of which ·620 was required by the magnesia, the remaining ·740 by soda, while the ·700 chlorine was equal to ·466 sodium.	
The water salts were therefore:	
Sulphate magnesia..........	·932
Sulphate soda............	1·334
Chloride sodium........	1·166
Loss...........	·188
C.—The pulverulent residue was acted on by muriatic acid with alcohol; it effervesced; after decantation the fluid was precipitated by oxalate ammonia, which, heated red, gave carbonate lime..................................	·680
Ammonia gave red oxide of iron.......................	·021
Phosphate of soda gave on concentration a trace of magnesia.	
D.—The remaining 11·53 was treated with boiling muriatic acid diluted, but with no alcohol; it was all dissolved but ·220, which was taken as silica, the sulphate of lime being	11·31

The solid contents of the water were then,

As found.		*As existing in the Water.*	
Chloride of magnesium . .	·747	Chloride of magnesium . .	·747
Chloride of sodium	·940 1·166	Chloride of sodium	2·106
Sulphate of magnesia	·932	Sulphate of magnesia	·932
Sulphate of soda	1·334	Sulphate of soda	1·334
Carbonate of lime	·680	Bicarbonate of lime	1·019
Carbonate of iron	·021	Bicarbonate of iron	·030
Carbonate of magnesia . . .	a trace.	Bicarbonate of magnesia . .	a trace.
Sulphate of lime	11·310	Sulphate of lime	11·310
Silica	·220	Silica	·220
	17·350		17·698
Loss, probably extractive . .	·188		
Water	1·543		
	19·081		

The author has some doubts whether the whole of the iron exists as bicarbonate; certainly by far the greatest proportion is in that state, because upon standing an ochre is deposited and the water has but a very slight action on iron tests. Some experimenters have imagined that a part was dissolved as sulphuret, and others have found the iron as metal upon evaporation; but Mr. Herapath found no direct evidence of the first; and as to the second he observes that every experimenter who found metallic iron had evaporated in a brass or other metallic boiler, which would easily account for its presence; but it is not unlikely that a small portion is held in solution otherwise than as bicarbonate.

The other water was found in Kingsmead-street. A well 59 feet deep and 40 feet boring had been upon the premises for some time, which contained water of the temperature of 76°, and from the heat of its sides it was evidently in the neighbourhood of hot water. As this spring furnished but 35 hhds. a day, and more was wanted, a boring hole was made which passed through the following strata:

35 feet of blue lias.
50 —— white lias.
11 —— white clay.
11 —— sulphur clay.
1 —— red soil.

108
59 original well.
40 original boring well.

207

When at this depth no water was found; but one morning upon the workmen arriving the well was discovered to be full of hot water to

within 7 feet 5 inches of the surface, and it was running over through a weak place in the side at a very rapid rate.

Examined June 4th, 1836; it was found discharging at the rate of 137 gallons a minute, and it was stated that the flow had been invariable from the month of November last; its temp. was 99°, and its s. g. at 60°, 1·001957.

Upon treating 8750 grs. exactly as that of the King's Bath, the following salts were obtained as existing in the water:

Chloride of magnesium	·673
Chloride of sodium	2·920
Sulphate of magnesia	1·105
Sulphate of soda	2·090
Bicarbonate of lime	1·170
Bicarbonate of iron	·016
Bicarbonate of magnesia	a trace.
Sulphate of lime and silica	11·472
	19·446

This water then is of the same class as the King's Bath, being thermal and chalybeate. It contains 1½ gr. more of solid contents in the imperial pint, and the proportion of the various ingredients differs.

The Bath waters have been repeatedly the subjects of analysis, but the results are very various, scarcely any two experimenters agreeing in the details, although the total quantity of solid matter is not so much a subject in dispute. Whether the water differs at distant periods, or the system of analysis followed is the cause of the disagreements, Mr. Herapath does not attempt to decide, but contents himself with placing the operations of each chemist in juxtaposition, supposing them to operate upon the old wine pint, which was the quantity referred to by them. The carbonates are assumed to have existed as bicarbonates.

Wilkinson.		Phillips.	Scudamore corrected by turning muriates into chlorides.	Herapath.
Chloride magnesium		,,	1·350	·630
,, sodium	3·045	3·24	,,	1·778
,, calcium		,,	1·000	
Sulph. magnesia		,,	,,	·791
,, soda	1·630	1·475	·900	1·132
Carb. lime	·797	·760	,,	Bicarbonate.. ·802
,, iron	·200	·00196	01·985	Do. ·025
,, magnesia		,,	,,	Do. a trace.
Sulphate lime	8·370	8·850	9·500	9·610
Silica	·180	·19	·200	·180
Extractive	·090		Loss. ·58015	
			Water. ·450	
	14·303	14·51696	14·0000	14·958

On the Analysis of Wheat, a peculiar Volatile Fluid, and a Soluble Modification of Gluten, Nitrogen in Lignin, &c. By W. C. Jones.

Having observed a peculiar liquid and soluble gluten in experiments to ascertain the quantity of starch, &c. which exists in ordinary wheat, the author first gives the results of his observations on the gluten and starch. He carefully separated the starch from 100 samples of wheat, every 10 of which were as nearly alike as possible, and the analysis given below is the mean of every 10 of the similar samples. Every one of the 100 samples was separated in two ways: the quantity of water was ascertained in one set of experiments by heating the meal at a temperature of 160° until no more was given off, the quantity of gluten by washing away the starch in the usual way, the quantity of soluble matter by digesting with water at a moderate temperature, and evaporating to dryness before fermentation was produced. In the other method of operating, which has been found the most accurate, the meal was mixed with four parts of water at a temperature of 68° Fahrenheit; the fermentation was allowed to go on, until the saccharine matter was converted into alcohol and the alcohol to acetic acid, which eventually dissolves every particle of gluten in the wheat. When the ingredients, viz., the meal and water, have been mixed 12 hours, the mass will swell up considerably, and the temperature will increase; in 12 hours more the solid parts will subside and the supernatant liquid will have a sweet taste, slightly acid, s. g. 1·018. When all the alcohol and other principles are converted into acetic acid (more acetic acid being formed than the alcohol would produce), and when the gluten is dissolved, the liquid will have an acid, bitter taste, and a gravity of 1·047; this change will occur in about 15 days. On evaporating this solution to dryness a peculiar form of gluten is obtained in reddish brown transparent gummy masses, smelling like the brown part of roasted beef, *very soluble in water and alcohol*. The acetic acid still contained in this gluten has some effect in rendering it so soluble in water, but only to a limited extent, as an alkali added to the aqueous solution causes $\frac{2}{10}$ths of the gluten to subside, the precipitate being soluble in alcohol.

By treating this gluten in a peculiar manner a series of azotized bodies may be obtained, peculiarly interesting in their properties and brilliant in their appearance.

Having obtained the gluten in this way the author inferred the quantity of saccharine matter by the alcohol and acid produced, the starch by the usual separation, and the bran by a hair sieve, drying carefully at a temperature of 100°: the results of both sets of experiments did not materially differ, and most of them were further corroborated by a third series performed in a very large way. Chemists in analysing wheat have included the starch under one head, and taken no notice of a low-quality starch which exists in wheat, and which must be separated to render starch fit for its ordinary uses. This low starch gives a reddish brown colour with iodine, and a *brown* jelly with water, but when torrified the amidine approaches to that from the usual starch. In the following analyses the small quantity of phosphate of lime existing in wheat is

of course included in the starch experiment. No. 2 was a very plump English wheat, and all the others were corn of the British empire, some thin and some plump grains, that sample being fullest which contained least lignin, and *vice versâ*.

	1. Mean of 10 similar Samples.	2. Mean of 10 similar Samples.	3. Mean of 10 similar Samples.	4. Mean of 10 similar Samples.	5. Mean of 10 similar Samples.	6. Mean of 10 similar Samples.	7. Mean of 10 similar Samples.	8. Mean of 10 similar Samples.	9. Mean of 10 similar Samples.	10. Mean of 10 similar Samples.	Mean of 100 Samples.
Fine Starch	33·45	34·00	33·55	34·11	32·44	33·33	32·80	34·10	31·99	33·39	33·316
Low Starch	9·34	9·23	8·90	9·21	10·00	9·11	8·90	9·10	9·87	8·77	9·243
Gluten	20·56	19·00	21·00	18·99	22·09	18·00	19·66	29·11	23·00	24·0	22·641
Saccharine and other soluble matter	6·52	6·90	5·42	7·00	5·11	8·34	6·55	7·00	6·19	5·16	6·419
Bran or Lignin	13·42	12·70	13·00	12·80	14·4	13·8	12·90	12·60	14·50	15·00	13·512
Water	12·56	13·5	13·00	13·70	11·19	12·10	14·11	13·30	10·90	12·00	12·636

From the above it will be seen that the manufacturer would be greatly deceived if he expected to obtain 60 per cent. of starch, as stated by some chemists ; he would in fact seldom or never obtain more than 34.

Kirchoff discovered that very diluted sulphuric acid would convert starch to sugar of grapes, and after long boiling Mr. Jones finds the concentrated acid will produce this effect immediately. Dry starch is, by addition of sulphuric acid, instantly converted into charcoal, and acetic or malic acid can be distilled from the mass; but if 1 part of starch be mixed into a paste with 1 part of water, and then $2\frac{1}{4}$ parts of sulphuric acid added, the starch is instantly dissolved: the solution has a temperature of about 200°, smelling strongly saccharine and æthereal, in fact a peculiar æther can be distilled from the solution. When the solution is diluted, and the acid removed, a light-coloured deliquescent sugar is obtained ; but only 63·8 parts of sugar are obtained from 100 parts of starch in this way, and it would be interesting to find in what form of soluble combination the other part exists, and perhaps this inquiry may tend to show the difference between starch and sugar, and throw some light on *isomeric* bodies.

Volatile Liquid.—When the lignin of wheat is separated in the humid way, dried at a temperature of 100°, and mixed into a paste with water to prevent charring, and sulphuric acid is then added in small quantities at a time, the bran will be dissolved, and the solution will have a dark brown colour, and a pleasant æthereal odour ; upon distilling this fluid a pungent liquid is obtained, smelling of hydrocyanic acid, though this cannot be detected in the solution. This fluid when rectified has a specific gravity ·9829 and boils at 186° Fahrenheit. When poured upon caustic lime, the lime slakes and becomes of a *bright yellow colour*, which appears to be peculiar to this fluid ; when boiled with lime-water the solution becomes dark orange ; pure ammonia, potassa, and soda change the brown liquid to yellow, but not orange ; the property of changing lime yellow did not exist in the most volatile portion of the solution only, as the liquid in the retort after distillation had that property also. An acid changes the brown to yellow, which an alkali restores, showing some analogy to the colouring matter of turmeric. Sup-

posing from its slightly reddening litmus, and the colour which originated from its combination with lime, that the fluid might contain a peculiar acid, the author precipitated the lime with oxalate of ammonia, thinking if the supposition was correct a coloured volatile salt of ammonia might be obtained. But on evaporating the supernatant liquid to dryness and heating to 300°, the colour still remained in a soluble state. Professor Hare, in a pamphlet he presented to the members of the Association, observed the tendency of sulphurous acid to change many volatile oils yellow, and it is not improbable that a portion was generated in this case as carbon always is produced in distilling the mixture. The author, strongly suspecting the liquid to contain nitrogen, though he could not see from what source it was derived, as the husk of wheat is mere lignin, and chemists assert that lignin does not contain nitrogen, adduces the following experiment to prove that the lignin of wheat does contain nitrogen: a portion was successively boiled in alcohol, water, and muriatic acid, washed and dried; from 112 lbs. he obtained on destructive distillation $1\frac{1}{2}$ lb. of sesquicarbonate of ammonia. Chemists have observed that the seeds of the cerealia contain nitrogen, but Mr. Jones was not previously aware that the lignin of the wheat contains the same principle. He has not analysed the volatile liquid quantitatively, but it contains carbon, hydrogen, oxygen, and nitrogen.

Notice of Experiments respecting the effects which Arsenic produces on Vegetation. By Dr. DAUBENY, *Professor of Chemistry, Oxford.*

Dr. Daubeny was led to undertake these experiments from having received a communication from Mr. Davies Gilbert, in which he stated that there was a district in Cornwall where the soil contained a large proportion of arsenic, and that no plants could grow in it except some of the Leguminosæ. By analysis, this soil yielded him about 50 per cent. of arsenic, in the form of a sulphuret, the rest being composed principally of sulphuret of iron and a little silica. He had already ascertained that a little of the sulphuret mixed in soils produced no injurious effect on *Sinapis alba*, barley, or beans, and that they flowered and seeded freely when grown in it. Although the want of solubility in the sulphuret might be assigned as a reason for its inactivity, yet it was certainly taken up by water in small quantities, and imbibed by the roots of plants. Upon watering them with a solution of arsenious acid, he had found that they would bear it in larger proportions than was presupposed. The experiments were made and are continued at Oxford.

On a new substance (Eblanine) obtained from the Distillation of Wood. By R. SCANLAN.

On a former occasion Mr. Scanlan described a new fluid obtained from pyroligneous acid, and he now detailed the properties of a new

substance of similar origin, but solid. It is of yellow colour, insoluble in water, but soluble in alcohol, from which it separates in long rectangular prisms. Upon analysis by Mr. Scanlan and Dr. Apjohn it was found to be composed of ten atoms carbon, five atoms hydrogen, and two atoms oxygen.

On the Insulation of Fluorine. By Mr. Knox.

Mr. Knox, by operating with vessels of fluor spar, had been enabled to confine this singular substance and submit it to ocular examination. He separated it from fluoride of mercury by dry chlorine, and obtained it in the state of a gas of a deep orange colour.

Dr. Dalton explained his views relating to Chemical Symbols, and compared the *method of representation* which he advocates with the *method of notation* sanctioned by Berzelius and other chemists. (See in this volume the Address delivered by Dr. Daubeny.

Mr. Babbage exhibited a Thermometer recently discovered in Italy, and supposed to be one of those originally manufactured for the Società del Cimento. It appeared to be filled with alcohol. The bulb was spherical; the stem was divided into 50 equal parts by beads attached to it by fusion at equal distances. The scale of these instruments having been adopted without reference to fixed points (as boiling water or melting ice), it is a problem of some difficulty to render the results obtained by the use of them comparable with the indications of modern instruments.

Mr. Babbage stated the progress in this research made by Libri, and the methods which he had employed for the purpose.

On a modification of the common Bellows Blowpipe. By Wm. Ettrick.

The author proposed to equalize the unsteady blast of the simple bellows blowpipe, by decreasing the usual size of the blower and giving it a rapid motion by means of a crank and multiplying wheels, turned by the hand or foot. A valve adjustible to any degree of pressure is placed on the upper bellows-board.

On a means of detecting Gases present, in small proportions, in Atmospheric Air. By William West, *of Leeds.*

The author proposes, by wind-sails or some similar means, to draw large measured quantities of air through liquids fitted to combine with the gases suspected.

Mr. Lowe exhibited crystals of iron pyrites produced on the clay which lines the iron pots, used in the manufacture of sal ammoniac. (See vol. iii. p. 582.)

GEOLOGY.

On certain points in Physical Geology. By WM. HOPKINS, *F.G.S.*

Distinct approximations to general laws have long been recognised in geological phænomena connected with the dislocations of the crust of the globe. In districts (as for instance our coal districts) where faults abound, they usually consist of two systems, those in the one meeting those in the other nearly at right angles, the faults in each system being approximately parallel. The same observation applies to anticlinal and synclinal lines, and to longitudinal and transverse valleys where they appear to be connected with lines of dislocation. The directions of mineral veins present to us striking approximations to the same laws; and further, it is important to remark with respect to all the phænomena now mentioned, that when they occur in stratified masses their directions are found to bear distinct relations to the disturbed positions of such masses, one system coinciding with the direction of the strike, and the other with that of the dip of the beds. Mineral veins also (or rather the fissures in which the matter properly constituting a mineral vein has been deposited) possess many characters in common. Their depth is uniformly greater than that to which man has been able to penetrate; the most productive veins in stratified masses are in the direction of the dip, the cross-courses in that of the strike of the beds, the latter being in general of considerably greater and much more irregular width than the former. The corresponding beds in the opposite walls of a vein are frequently at different elevations, thus forming what is called the THROW of the vein; the planes of most veins approximate to verticality; insulated masses of the adjoining rock (termed *riders*) are often found in them; and finally, at their intersections they frequently present various appearances of relative displacements. Trap and granite veins and horizontal beds of trap are also phænomena which must be regarded as associated with the elevatory movements to which the crust of the globe may have been subjected.

That the appearances of fracture in the earth's crust are not illusory, but afford certain indications of actual dislocation, it would appear impossible to doubt in the present state of geological inquiry; and hence we are naturally led to the inference that some dislocating force must have acted beneath the fractured crust, and moreover that its action must have been *general and simultaneous*, at least to the extent of the districts throughout which the phænomena follow the same laws without breach of continuity. Assuming this to be the case, Mr. Hopkins's object has been to institute an investigation, founded on mechanical and physical principles, and conducted according to mathematical methods, to ascertain how far the phænomena above-mentioned are referrible to the cause to which we have been led to assign them.

The author makes no hypothesis in these investigations as to the manner in which the elevatory force is produced; he merely assumes its simultaneous action under portions of the earth's crust of considerable extent. With respect to the constitution of the elevated mass in its undisturbed state, it is sufficient for the strict applicability of his re-

sults, that its cohesive power should vary according to any continuous law in passing in any direction from one point of the mass to another, or according to any discontinuous law in passing along a vertical line, so that a difference of constitution in the successive horizontal strata of a stratified mass is of no importance. The effects of planes of less resistance existing irregularly in the mass are also taken into account.

Taking a mass thus constituted, Mr. Hopkins investigates mathematically the manner in which fissures will be formed in it when subjected to tensions in assigned directions impressed on it by extraneous forces, and sufficient to overcome its cohesive power. After thus establishing various propositions, he proceeds to apply them to the dislocation of the crust of the earth, the tensions to which the mass is, in this case, subjected being produced by its elevation and consequent extension.

One of the first inferences from this theory is that the directions of dislocation must in general bear definite relations to what may be termed the actual geological conformation of the disturbed district, *i. e.*, to that external form which would be presented to us if any one originally unbroken horizontal stratum extending throughout the whole mass were at present to form its surface. In many cases it is easy to determine these relations; in others it is more difficult to do so, particularly in those in which the disturbed district is of limited extent, and irregular form and boundary. If there be a distinct *axis* of elevation, our system of fissures (always supposing them referrible to the cause here supposed) will be parallel to it, whether curvilinear or rectilinear; and if another system exist, the fissures composing it must meet those of the former system approximately at right angles. If there be a distinct *centre* of elevation our systems will diverge from it, and another system may exist concentric about it. The latter kind of elevation will in general be on a much more limited scale than the former, and may be frequently superimposed upon it; and if this kind of double elevation take place at once, a corresponding modification will result from it in the directions of the fissures. Two or three striking examples of this kind were selected by Mr. Hopkins from the mining district of Derbyshire and the adjoining coal district of Nottinghamshire, which, while they appeared to offer obvious exceptions to the *law of parallelism* as usually interpreted, are strictly in accordance with his theory.

Another important inference from this theory is that of the *simultaneous formation* of any system of fissures such as above mentioned, as far at least as regards *the decided commencement of their formation*. If there be two systems, they may either have been formed at the same or at different epochs.

These fissures must be regarded as the *primary phænomena* of this branch of the science. The *secondary* ones of faults, mineral veins, anticlinal lines, &c. &c. are easily deducible from them. It is impossible, however, in a limited abstract to enter into the particulars of this part of the subject, which may be found in considerable detail in the author's original memoir, in the *Transactions of the Cambridge Philosophical Society*, vol. vi. part 1.

Another view of the phænomena of elevation consists in regarding

the directions and positions of the primary fissures as determined by a regular structure of the mass (such as the jointed or laminated structure) superinduced *previously to its elevation*. Mr. Hopkins thought it highly probable however that if such were the case the dislocations would be much more numerous in any disturbed district, and much less continuous than they are observed to be. He wished particularly however to impress on the minds of geologists that the claims of the two theories, one of which would assign the directions of the lines of dislocation to the mode of action of the dislocating force (as explained in his memoir), and the other to the previous constitution of the dislocated mass, must be ultimately decided by observation; and to enable observers to do this, he begged to direct their attention to two or three points in particular, which might, probably, in many cases, decide the question.

1. If the lines of dislocation which we observe in the superficial portion of the earth's crust were determined by the jointed structure which we now observe in that portion, there must manifestly be, not an approximate, but an *accurate coincidence of the joints and dislocations*. Wherever such is not the case, we have an indubitable proof that the joints in the *upper portion* of the dislocated mass could not have been so far developed as to exercise any material influence on the directions of dislocation.

2. It may be conceived however that the *lower portion* of the mass may have been so far jointed at the period of dislocation as to determine the directions of fracture in the upper part. To determine the truth of this hypothesis, the directions of the joints in the primitive rocks should be carefully examined at points nearest to the observed systems of dislocation, to ascertain how far this accuracy of coincidence or the absence of it can be established. The want of it must necessarily be conclusive, while its existence is inconclusive evidence as to the point in question. Further tests must be sought for by examining the directions of the lines of fracture in the proposed district; whether for instance they are related to an *axis* or to a *centre* of elevation, or whether they present distinct local deviations from the general law of the district, connected with any peculiar local geological conformation. If such deviations be found, it must then be considered how far they are inconsistent with the theory Mr. Hopkins has investigated, or with the general laws which careful observation may hereafter establish respecting the directions of well-developed systems of joints. It is by these or similar observations, and not by any preconceived notions as to the constitution of the dislocated mass, that the question at issue must be decided.

Mr. Hopkins elucidated these observations by a reference to the limestone, grit, and coal districts of Derbyshire and Nottinghamshire, in which two general systems of dislocation are well developed, the one being N. and S., the other E. and W., but presenting some local deviations from this law curiously in accordance with his theory. In the same districts (more particularly in the limestone) there exist two extremely well defined systems of joints nearly at right angles to each other, and running very nearly magnetic N. and S. and E. and W.

These joints therefore cannot have determined the directions of dislocation, while the local deviations just alluded to, so far as nothing similar to them has yet been observed in the directions of joints, offer a strong proof that the lines of fracture have not been determined by the joints of the inferior portion of the mass, but by the mode of action of the elevatory force.

Notes on the Sea Rivulets in Cephalonia. By Lord NUGENT.

At the extremity of a rocky promontory, *Point Theodori*, in the harbour of Argostoli, streams of water may be observed rushing inland by means of large fissures; and Lord Nugent stated that Mr. Stephens had excavated pits and channels which he had turned to a profitable purpose by placing a mill in its course. The level of the water appears to be regulated by the height of the tide, and by the fresh waters which occasionally flow in.

On the State of the Chemical Theory of Volcanic Phænomena. By C. DAUBENY, *M.D., F.R.S., Professor of Chemistry, Oxon.*

In this communication Dr. Daubeny reviewed the hypothesis of volcanic action involving chemical principles, and defended the opinion which ascribes volcanic excitement to the admission of water to the metallic bases of the earths and alkalis in the interior parts of the earth.

On Voltaic Agencies in Metalliferous Veins. By R. W. FOX.

R. W. Fox submitted to the Geological Section an experiment tending to show that the native yellow, or bisulphuret of copper, is convertible into the grey sulphuret of that metal by voltaic agency. To effect this he employed a trough divided into two cells by a mass or wall of moistened clay. In one of these cells he put a piece of the yellow sulphuret of copper, and a solution of the sulphate of copper; in the other cell a piece of zinc, attached to the copper ore by means of a copper wire which passed over the clay, and he filled the latter cell with water. This simple voltaic arrangement quickly changed the surface of the copper ore from yellow to beautiful iridescent colours, afterwards to purple copper, and finally, in a few days, to grey copper, on which metallic copper was abundantly deposited in brilliant crystals. He considered that the oxide of copper in the solution parted with its oxygen to one portion of the sulphur of the bisulphuret of copper, thus forming sulphuric acid, which was transmitted by the voltaic action through the clay to the zinc in the other cell, whilst the deoxidized copper was deposited on the *electro-negative* copper ore.

These results seemed to explain the reason why metallic copper is often found in contact with grey and black copper ore in our mines, and not with the yellow sulphuret of that metal, and likewise, why the former generally occurs in metallic veins, nearer the surface and cross courses than the yellow sulphuret; in fact, in situations in which it is

most exposed to the action of ferruginous matter, as indicated by the *gossan*, and of waters holding salts in solution. The *gossan* of the Cornish miners is a sort of iron ochre, which usually abounds in copper veins, but not in those of tin, and Mr. Fox obtained a substance closely resembling it by substituting a solution of the sulphate of iron for the sulphate of copper. He likewise mentioned his having found that when the muriate of tin in solution was placed in a voltaic circuit, a part of the tin accumulated at the *negative* pole in a metallic state, and the remainder at the *positive* pole in the state of a peroxide, the same as it exists in the mines, and he considered that this experiment is calculated to explain why tin and copper ores so commonly occur in different veins, or in different parts of the same vein.

He alluded to a paper of his which had been read before the Geological Society, in which he referred the definite arrangement of the ores in different rocks to voltaic agency, and assumed that the fact of veins being often found productive of ore in one rock and barren in another might be due to the relative electrical states of those rocks when the depositions took place, and he conceived that the prevalence of different salts in solution in the minute fissures of different rocks might, amongst other causes, have tended to generate voltaic currents. The water taken from the mines which he had examined differed exceedingly in the nature and proportions of the saline matter which it contained; and he had obtained considerable voltaic action by the influence of different ores on each other, such, for instance, as a piece of yellow, and another of grey copper ore, separated by clay which was moistened with water taken from the same mine as the ores were.

Mr. Fox thought that the prevailing direction of metalliferous veins might be connected with that of magnetic forces; the former is nearly at right angles to the present magnetic meridian. He moreover stated his reasons for thinking that the phænomena of the intersections of some veins by others are not incompatible with the contemporaneous formation of the original fissures in opposite directions, on the hypothesis of their having undergone a progressive opening; and he considered that the proofs of such progressive opening abounded in the Cornish lodes and cross courses, the larger veins being commonly divided into smaller parallel veins, having walls resembling the outer walls, between which all were included. Thus he supposed that tin veins were intersected by copper veins in consequence of the latter being less hard than the former, and containing in general more clay and other mechanical deposits, whilst cross courses have still more of such mechanical deposits, and intersect both tin and copper veins; for if we suppose such veins, nearly at right angles to each other, to be cracked or further opened, it is evident that the rent in the metallic vein might be rapidly filled up with clay or other matter conveyed into it by the water circulating in the veins.

Remarks illustrative of the Physical Geography of the Pyrenees, particularly in relation to Hot Springs. By Professor FORBES.

The author attempted to embody in this communication the results, more particularly geological, of a recent tour to the Pyrenees, and which form part of a paper recently read to the Royal Society of London. The intimate relations of hot springs to certain classes of rocks had before been observed, and the occurrence of granite as characterizing these thermal sites is so striking as not to escape the most superficial observer. The author remarks in addition that these springs rarely or never appear in the heart of a granite country, but on its borders, or at least near where stratified rocks occur in contact with granite. He quoted many examples in proof of the assertion, but one of the most striking is found in the department of the Pyrenees-Orientales, where an insulated deposit of stratified rock surrounded by granite, has its outskirts or line of junction studded with hot springs.

Stratified rocks under such circumstances are usually altered in their texture and composition, and the author shows that even where the granite does not directly appear its action may be inferred from the metamorphic character of the rocks and frequently from the fissures and contortions which accompany that character. The author includes the whole of Charpentier's "Barèges formation," or primitive trap slates, in this class, and to their occurrence attributes the hot springs of Barèges, St. Sauveur, and Cauteretz. Lastly, he shows that the quantity of metalliferous deposits in the Pyrenees seems intimately connected with the occurrence of the hot springs, being their almost invariable concomitants. He showed in a tabular view (which will be published in the *Phil. Trans.*) the number of coincidences of the five following coordinate phænomena:—Hot springs, elevatory or intrusive rocks, metamorphic rocks, lines of fissure and elevation, metalliferous veins.

The author explained the importance which he attaches to an accurate determination of the temperature of these springs, and the precautions which he observed in order to make them comparable at future periods with observations which may be then made; and that the very few old observations of any value seem to indicate no decided change of temperature. The principal spring at Barèges cannot have changed half a degree of Fahr. in a century. The author also noticed the capricious intermingling of springs of every kind in such a way as to separate completely the phænomena of mineralization and high temperature. In some parts of the Pyrenees hot springs of pure water, pure cold springs, mineral hot springs, and mineral cold springs rise within a few yards of one another.

On certain Phænomena connected with the Metalliferous Veins of Cornwall. By H. T. DE LA BECHE, *F.R.S., G.S.*

Mr. De la Beche brought forward observations on the directions, breadth, intersection, and other characters of mineral veins; described the relations of the veins to the adjoining rocks, and to the natural

divisional planes in them; and explained the bearing of these data on the general question of the origin of the fissures now filled by the mixed or distinct masses of sparry, metallic, and earthy matters which constitute mineral veins.

A Notice of the Remains of Vertebrated Animals found in the Tertiary Beds of Norfolk and Suffolk. By EDWARD CHARLESWORTH, *F.G.S. &c.*

The author brings forward this paper principally with a view to substantiate the fact that some of the marine fossiliferous deposits on the eastern coast of England, belonging to the *tertiary* epoch, contain the remains of extinct and existing species of terrestrial mammalia, clearly contemporaneous with the shells and other organic bodies associated with them.

In 1835 the author described a newly-discovered bed of fossils separating the crag from the London clay at various localities in Suffolk, which he proposed to call "Coralline crag," suggesting at the same time the term "*Red Crag*" as an appropriate designation for the overlying ferruginous shelly strata with which geologists were already familiar. Having never detected the remains of mammalia in either of the above-named deposits, and believing that the crag of Norfolk was merely an extension of the upper or red crag of Suffolk, the author, in common with Professor Phillips and some other geological writers, had thrown doubts upon the existence of the bones of elephants and other land animals in the tertiary beds of the former county, believing that their supposed occurrence probably originated in the erroneous identification of diluvium with crag; the extremely superficial character of the latter, and the abrasion to which it has in some places been exposed, rendering a precise separation of the two a matter sometimes of considerable difficulty.

A recent examination however of Norfolk has produced a totalc hange in the opinions previously entertained by the author upon this subject, for he finds that not only are the bones of land animals constantly found in the so-called crag of that county, but that they are of most frequent occurrence in those particular beds which furnish the strongest evidence of tranquil deposition; and further, the bones strictly belonging to these beds of marine origin can be at once distinguished from those of the overlying diluvial or lacustrine deposits by the peculiar chemical change which the former have undergone. The list of mammalia enumerated by the author belonging to the tertiary period includes six or eight species of rodentia and ruminantia, one of the genus lutra, besides teeth of the elephant, hippopotamus, and mastodon. Dr. William Smith was the first who announced the discovery of the mastodon in our own country, and though geologists have generally refused to place it upon the list of British fossil pachydermata, the existence of this genus has recently been most completely established by the researches of Mr. Fitch and Mr. Woodward of Norwich, and Captain Alexander of Yarmouth.

The author in the next place proceeds to discuss the relation which this mammiferous stratum bears to the two tertiary deposits of the adjoining county, showing that it is not, as he had anticipated, an extension of the red crag of Suffolk, but a deposit altogether distinct from it and the coralline, differing essentially from both in the number and nature of its organic contents. Its geographical limits are not confined to Norfolk, since it may be traced from Norwich to Aldeburgh in Suffolk, overlying some part of the coral reefs in that most interesting locality. It may be most advantageously examined in the immediate neighbourhood of Norwich; at Southwold, and on Thorp Common near Aldeburgh. This stratum as regards relative age may be looked upon as holding a station intermediate to the red crag, and those deposits in which the testacea appear to belong almost exclusively to existing species of mollusca.

The beds above the chalk in Norfolk, Suffolk, and Essex may be grouped into two sections, determined by the presence of terrestrial mammalia throughout a part of the series, which in descending order will be as follows:—

Beds containing numerous remains of terrestrial mammalia.

1. Superficial gravel, containing bones of land animals, probably washed out of stratified deposits.
2. Superficial marine deposits of clay, sand, &c., in which the shells very few in number (10 or 15 species), may all be identified with such as are now existing.

Examples.—Brick earth of the Nar, Norfolk.

3. Fluviatile and lacustrine deposits, containing a considerable number of land and freshwater shells, with a small proportion of extinct species. (Mammalian remains in great abundance.)

Localities.—Ilford, Copford, and Grays in Essex. Stutton in Suffolk.

4. Mammiferous crag of Norfolk and Suffolk, hitherto confounded with red crag, containing about 80 species of shells: proportion of extinct species undecided.

Localities.—Bramerton near Norwich; Southwold and Thorp in Suffolk.

Beds in which no traces of terrestrial mammalia have yet been observed.

5. Red crag, containing 150 to 200 species of shells: proportion of extinct species undetermined.

Localities.—Walton and Dovercourt, Essex; Felixstow, Newbourn, and Bawdesey, Suffolk.

6. Coralline crag, containing 3 to 400 species of shells: proportion of extinct species undetermined.

Localities.—Ramsholt, Sutton, Tattingstone (beneath red crag), Aldeburgh, Orford.

7. London clay.
8. Plastic clay.

The author next adverts to the remains of birds which he has recently obtained on several occasions in the mammiferous stratum of

crag. The bones, principally belonging to the phalanges, have not yet been minutely compared with the corresponding portions of skeletons of existing species. These remains occur at Southwold, and have undergone the same chemical change as the bones of mammalia.

No remains which can be satisfactorily referred to the reptilia have been discovered in the crag.

The remains of fish are very abundantly dispersed throughout the red and mammiferous crag, but are less plentiful in the coralline. Occurring only as detached bones, it is not very easy to arrive at any very satisfactory results in their examination. Their distribution throughout the three deposits is as follows:—

Mammiferous Crag.—Bones of the genus Platax in immense numbers; several species of the genus Raia, vertebræ of genera totally new to Agassiz.

Red Crag.—Teeth of Carcharias, several species, including *C. Megalodon* of Agassiz; palates of Myliobatis; teeth of Lamna, Notidanus, Galeus.

Coralline Crag.—Genera undetermined.

On the Fallacies involved in Mr. Lyell's Classification of Tertiary Deposits according to the proportionate number of recent Species of Mollusca which they contain. By E. Charlesworth, *F.G.S.* (The abstract of this communication has appeared in Jameson's Edinburgh Phil. Journal; and the author has subsequently treated of the subject in the Phil. Mag. and Annals for January, 1837, and also in the new Series of Loudon's Magazine of Natural History.

On certain Limestones and associated Strata in the Vicinity of Manchester. By Professor Phillips, *F.R.S., &c.*

The subjects treated of in this Memoir were those members of the saliferous and carboniferous formations near Manchester which offered circumstances of interest in the general study of these deposits, or specially important as bearing on a general conclusion presented by the author, that between Manchester and Shrewsbury a great deposit of coal probably exists below the new red sandstone rocks, though, from its want of conformity to these rocks, and the great depth at which only it could be found, the search for it might be at this moment unadvisable.

Referring to the previous notices of thin limestones associated with coloured marls and inclosed between rocks of red sandstone at Collyhurst near Manchester, the author proved by sections and analysis of specimens, and accounts of organic remains, that these certainly belonged to the magnesian limestone formation. On the contrary, the limestone of Ardwick, near Manchester, was proved to belong to the upper part of the coal formation, and to contain, in its position with reference to the coal, its fossil remains, mineral composition, and associated deposits, perfect evidence of identity with the limestone of the Shrewsbury coal-field, first noticed by Mr. Murchison.

The author having recognised in the Ardwick limestone the same minute shells (*Microconchus carbonarius*, Murchison) which exist in the rock, at Le Botwood, Pontesbury, Uffington, &c. near Shrewsbury, and found similar plants in the neighbouring shales, and a similar succession of strata, was induced to visit some localities in Shropshire to complete his knowledge of the facts before stating his conviction that the limestones of Shrewsbury and Manchester were deposited in the same great branch of the sea, under circumstances so very similar as to render it very probable that they and the coal strata about them were really parts of a continuous deposit. (The organic remains hitherto collected by different individuals from these deposits were described by the author, who ascribes to Dr. Phillips of Manchester the honour of first recognising the true geological relations of the Ardwick limestone.)

On the Removal of large Blocks or Boulders from the Cumbrian Mountains in various directions. By Professor Phillips, *F.R.S., &c.*

This communication was intended to convey information on a subject proposed by the Committee of the Geological Section at the Dublin Meeting. Confining himself, for the sake of an accurate induction, to a case within his own personal knowledge, the author described the geographical and geological features of the North of England, and traced the distribution of blocks of granite, sienite, metamorphic slates, and other rocks of the Cumbrian mountains in various directions.

Contemplating this detritus, with reference to its abundance, the form and magnitude and nature of the masses, the configuration of the country over which they have been drifted, and the distances which they have thus reached from their native sites, the author stated as a general conclusion that in all the ascertained examples the distribution of the detritus from the Cumbrian mountains was such as no existing watery agencies could explain, nor any imagined simple relation of the level of land and sea allow; but that the phænomena required the somewhat difficult supposition of most powerful currents of water, guided in their direction by the general configuration of the land as it now appears, and assisted in their effect not merely by a single elevation of land, but by several risings and sinkings. The influence of the existing relations of the masses of land on the dispersion of boulders was shown by examples in the Vale of Eden, the Vale of York, the western border of Lancashire, &c., and the Pass of Stainmoor, in all which, and many other cases, the detrital masses were found to be accumulated against the ranges of high ground, and never to have passed these natural barriers except at comparatively low points. It was thus evident that the causes, whatever they were, which produced the phænomena were not capable of overcoming, except in a limited degree, the natural obstacles of the country, and this condition must be fulfilled in any satisfactory theory of diluvial action.

The hypothesis that extensive deposits of detritus, such as there described, were accumulated before the land was raised above the sea,

would remove much of the difficulty experienced in the study of this subject, but it appeared not generally applicable to the examples in question, because of the evidence afforded by ossiferous deposits and caverns in Yorkshire, that some parts of the country were dry land at the time of the occurrence of the diluvial floods.

On the Ancient and Modern Hydrography of the River Severn. By R. I. Murchison, *V.P.R.S.*

On the western side of the Vale of the Severn, Mr. Murchison has observed the distribution of coarse gravel to be generally such as implied local action of water from the N.W. to the S.E., or down the slopes of the rocks, as they decline from the principal axes of elevation which run N.E. and S.W., and in the arrangement of the boulders of Cumbrian rocks which pass in a long line of drift through Lancashire and Cheshire to the plains of Shrewsbury and the Vale of the Severn, he found reason to conclude that between the Mersey and the Bristol Channel the waters of the ocean had flowed in a strait, and there had distributed the detritus. This strait must have existed in a comparatively recent geological period, since the remains of many marine mollusca now living on the shores of England abound in some of the gravelly deposits on the line of what is presumed to have been a former channel of the ocean. In accounting for the position of the great boulders, coarse gravel and sea-shells, found at *different heights*, the author expressed his belief that they were all accumulated under the sea, and converted into dry land by *movements of elevation of unequal intensity*.—See *Abstracts of the Geological Society's Proceedings.*

On the Bone Cave in Carboniferous Limestone at Cefn in Denbighshire. By J. E. Bowman.

The author, referring to a memoir by the Rev. Edw. Stanley in the Edinb. New Phil. Journal for Jan. 1833, and to a ground plan which accompanies it, gives the following description of the present state of the cave. The recent excavations have been carried on in the main cave about 25 feet beyond D, and as far in the inner lateral fissure, commencing at 6*. The floor has also been sunk 3 to 4 feet along its whole extent by the removal of an immense quantity of diluvium and bone earth, and is now on a level with the entrance. Holes have been dug in several places down to the solid rock, which was very uneven and free from stalagmite in every instance.

A perpendicular section of the intruded matter, as now laid bare at the inner extremity of the main cave, exhibits the following appearance, commencing about 18 inches below the roof:—A series of innumerable thin beds of impalpable silt, some reddish, and irregularly alternating with others of different shades of pale ochre, slightly micaceous, the

* All the references are to Mr. Stanley's ground plan.

whole when dry easily separating into laminæ, often not thicker than the $\frac{1}{16}$th of an inch; the reddish beds effervesce with acids, but not so the ochrey micaceous ones. The whole series varies from 18 inches to two feet and a half in depth in different places, and rests upon a stratum of marl or clay two feet thick, which imbeds a few water-worn pebbles of greywacké and angular pieces of limestone, and a little way from the top contains some fragments of bone. Lower down the proportion of the latter increases, so much so that the middle portion consists almost wholly of a mass of broken and splintered bones much decayed, and some teeth, closely jammed together by a mixture of clay and comminuted bone earth. Among the teeth those of bears, hyænas, the rhinoceros, of ruminating animals, and probably of the hippopotamus have been recognised, and on a few of the broken bones are evident marks of the teeth of carnivora. This stratum imperceptibly passes below into another of very compact coarse diluvium of clay and pebbles of clayslate, with a few splintered bones and broken stalactites, also about two feet thick and reaching down to the present artificial floor. On breaking up this floor the writer found a series of beds of coarse and fine sand, alternating with others of loam and clay, precisely as may be seen on the bank of a river, but without any bones, pebbles, or shells; the whole about three feet thick, and resting on the solid limestone rock.

Another section at the extremity of the lateral fissure on the right corresponds in every respect, except that in the middle of the bone stratum is an additional interpolated series, about 20 inches thick, of the thin beds of parti-coloured silts, already described, which here contain a few small pieces of bone, and alternate with other beds of fine calcareous matter, probably bone earth. This series has also a horizontal arrangement, and seems to have been deposited by water in a hollow in the bone stratum.

Mr. Bowman then describes the strata found below the present floor in the anterior portion of the cavern, the material that formerly blocked it up even to the roof having been long since removed. For some yards round B the floor is a perfectly horizontal layer of stratified stalagmitic matter, 18 inches to two feet thick; and below it is a bed of yellowish ochrey loam, very different to the marly diluvium already described, but containing, like it, smooth pebbles of primitive rocks, pieces of limestone, broken stalactites, with some splintered bones and teeth of carnivora and ruminantia. It is of uniform complexion down to the solid rock, a depth of from four to five feet. In another excavation nearer the mouth of the cave the stalagmitic matter is replaced by sand, but below is the same ochrey loam, &c., with molar teeth of bears and fragments of jaws, and a few quartz pebbles; while in a third, at the very entrance, about three feet of gravel and coarse sand was found under the loam, without bones, some of the polished clay slate pebbles being from nine inches to a foot in diameter. Below is the solid rock slanting inwards from each side, and about five feet lower in the middle than the footpath in the front of the cave.

There are, therefore, at the extremity of the openings, 1st, a series of fine silts; 2nd, the marl overlying and passing into the 3rd or bone

stratum; 4th, the lower marl or coarse diluvium with very few bones 5th, the beds of sand, extending down to the limestone rock. Again, near the entrance are, 1st, the bed of sand and stalagmite forming the present floor, on about the same level with the bottom of the 4th or lower marl just named; 2nd, yellow ochrey loam, with bones, &c., extending along the vestibule from A to B, and passing down to the solid rock, but at the entrance resting upon coarse gravel. There is no trace of the ochrey loam deposit at the upper end of the cave.

The author forbears to speculate further on the above appearances, than to consider the upper series of fine silts to have been derived from two different sources, viz., the red and more compact layers from infiltrations of the decomposed limestone of the cave, and the ochrey micaceous and more friable ones from water entering the mouth charged with a muddy sediment of the decomposed primitive rocks of the neighbourhood, and having a common origin with the water-worn pebbles so abundant within and about the cave. That the valley was occupied by water to at least the level of the cave before the deposition of the ossiferous strata, is proved by the beds of sand and smooth pebbles underneath. Immense masses of these pebbles, more or less water-worn and mixed with diluvium, mask the face of the limestone rock in many places, and lie even on its summit, 40 or 50 yards above the level of the cave. Appearances about a very picturesquely perforated rock much below it, show that this diluvium must have been transported hither long subsequent to the disruption and elevation of the limestone, and that not simultaneously, for the pebbles still adhere to its irregularly excavated sides, and there is an intermediate horizontal layer of them of smaller size.

The author does not decide whether there are two distinct deposits of bones, viz., one in the yellow loam under the vestibule, and another at the upper extremity of the cave; though the different materials in which they are respectively found, the disparity of level, and the intermediate beds of sand, favour such a conclusion.

From the concave trough-like shape of the sides about the entrance, as well as from the beds of sand and gravel within, the author infers that the cave must once have been a water-course; for the abraded portions have been scooped out, alternately right and left, precisely in those places to which, from the opposite projections, the water-borne pebbles would have been driven with the greatest force.

On an additional Species of the newly-discovered Saurian Animals in the Magnesian Conglomerate of Durdham Down, near Bristol. By HENRY RILEY, *M.D., and* SAMUEL STUTCHBURY, *A.L.S.**

The remains about to be described were found in quarrying the brecciated beds of dolomitic conglomerate, which rests upon the highly in-

* In March, 1836, a paper from the same authors was read before the Geological Society of London, entitled, "A description of various Fossil remains of three distinct Saurian animals discovered in the autumn of 1834, in the Magnesian Conglome-

clined carboniferous limestone at the south-eastern extremity of Durdham Down, near Bristol.

Having in the memoir read some time since before the Geological Society entered into the particular characters of this formation, it is not necessary here to repeat them further than to show the proofs of this deposit being formed upon the spot, and not the effect of accumulated drift.

"In all the dolomitic formations we have been enabled to examine in this neighbourhood, we find them composed of fragments of the rock on which they rest. These observations equally apply to the conglomerate beds of the new red sandstone. For instance, in the quarry from whence these bones have been recovered, fragments of the limestone only upon which it rests are found. In the beds which rest upon the old red sandstone, such as those of Ham Green, Valley of Kein, Thornbury, &c., it is found to be composed of quartzose pebbles, fragments of friable sandstone, and limestone boulders, in fact the precise components of the conglomerate beds of the old red sandstone which they immediately overlie. In the conglomerate or brecciated beds of the new red, which occur in the New Cut or River, and flank Brandon Hill, are found pebbles of quartz and of compact millstone grit, precisely identical with the formation of Brandon Hill itself.

"From these facts it naturally follows that the animals were destroyed at a period of great local disturbance without transport from a distance or great movement. If the latter had taken place the bones would have been distributed over a large space, and not as now confined to a spot not exceeding half an acre in extent; besides which, although the limestone and bones themselves were dislocated and fractured to a great extent, still there is no evidence of abrasion.

"That the magnesian cementing paste was once subtile and fluid is exhibited in all the bones, and beautifully evidenced in a fragment of jaw which is exhibited to the Section, in which will be seen the submaxillary canal, filled as if injected, also the alveoli of the jaw, hollows of the teeth, &c. That it quickly became viscid and tenacious is also evidenced by its holding up in its substance the portions of bones and fragments of limestone even of great weight, while smaller portions had gravitated to the bottom. In many instances, although the bed of dolomite is now at this place near twenty feet thick, some of the bones were found even resting upon the carboniferous limestone itself, and by careful selection would represent fossils occurring in the last-named formation."

The authors next describe the various bones which had been collected: as the right half of a lower jaw with teeth; an ulna; a radius; a metatarsal bone; an ungual phalange; two left ilia; an ischium; a left femur; caudal vertebræ; and discuss *seriatim* their relations to existing and extinct forms of Saurians.

rate on Durdham Down, near Bristol; by Henry Riley, M.D., and Mr. Samuel Stutchbury." In the above-mentioned memoir the authors have established two new genera: 1st, *Palæosaurus*, of which they describe two species, *P. cylindrodon*, and *P. platyodon;* 2nd, The codontosaurus, the species of which they had not designated.

The authors then proceed to some general views:

"To make our present notice more complete it will be necessary to extract from a former memoir the characters exhibited by a section through the axis of the vertebræ, which exhibit a peculiar form in the spinal canal. In this section we have a mould of the vertebral or spinal canal formed by the matrix showing a very peculiar form in the upper portion of the annular element, forming the inferior boundary of the canal. Thus its inferior surface would not be on one level plane like other vertebral canals, but would present a succession of hollows or depressions corresponding to the body of each vertebra, for the inferior surface would present a concavity to the depth of $\frac{8}{10}$th of an inch in our specimen.

"In this way the vertical diameter of the canal would, at the middle of each vertebra, be at least one third more than at either of its points of junction with the next vertebra: traces of the same peculiarity may be found in other specimens.

"If we retrace our steps we shall find the pieces lately under review presenting at least two types.

"To the first belong the caudal vertebræ with the chevrons, and the two others described immediately after them; that is, a sacral and first caudal; the two ilia and ischium, the large and small femur, and the phalanges.

"To the second the series of caudals without chevrons, and the remaining bones of the members.

"The association of the piece of jaw with the latter would be assuming more than we could prove; although its characters are more those of a lizard than a crocodile, yet we cannot show that it belonged to the same animal, for it might have belonged to another extinct subgenus of lizard. We must recollect that the blocks of stone in which these remains are met with, are sometimes so filled with bones that they would be called osseous breccia by those not aware of their origin. This is a sufficient proof of the multitude of animals whose remains are here enveloped in the magnesian conglomerate, and at the same time a plausible justification of our opinion, that by a careful examination and study of these remains we shall be enabled to make out several subgenera of Saurians, independently of the remains of fishes.

"It is singular that in all the vertebræ hitherto met with in this locality we should find the double concave system only. We have already dilated upon the greater resemblance of the vertebræ to the crocodilian type than to any other; we have moreover pointed out analogies with other parts of their skeleton.

"The occurrence of crocodilian remains is both frequent and numerous in Great Britain as well as elsewhere: an examination of them according to their geological position, commencing with those at present in existence on the surface of this earth, and extending to those found in the new red sandstone of Guy's Cliff by Mr. Conybeare, and the instances before us from Durdham Down, will show a regular series of progressive changes in the type of their vertebræ, from the concavo-convex of the present day to the same in the newer extinct spe-

cies, and thence through the gradually disappearing concavo-convex to the superficially double concave, and to the deeply concave instances before us.

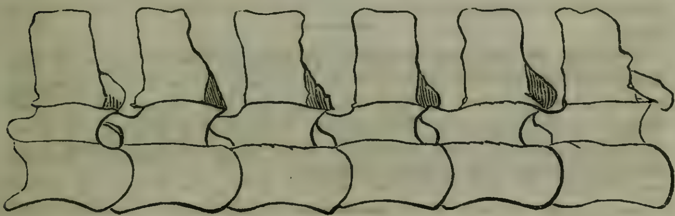
"In the lizards, with the exception of the monitors, we have the same order of phænomena.

"We should therefore have a right to conclude that the double concave system is more ancient than the concavo-convex, and that the deep concavity indicates an earlier state of existence than the superficially concave; seeing that the Durdham Down specimens are more ancient than those of the chalk, of Honfleur, Caen, Sussex, Monheim, the Jura, &c. &c.

"To carry this disquisition further, to attempt to show a succession of creations or changes from the ichthyoid type to the crocodilians (ascending as in the diagram), would require an infinitely more profound acquaintance with the subject than is at present attained.

"We nevertheless think ourselves justified in the assumption that the saurian type approaches the ichthyoid by two parallel lines, the one represented by the crocodiles, the other by the lizards."

Recent Crocodile.



Lumbar Vertebra. *First Caudal V.* *Second Caudal V.*

New Saurian.

Locality.	*Type.*	LIZARDS.	Saurians.	CROCODILES.	*Type.*	*Locality.*
Wealden.	Concavo-convex,	Iguanodon,		Steneosaurus,	Concavo-convex,	Honfleur.
Maestricht.	Concavo-convex,	Mososaurus,	Ascending to	Teleosaurus,	Superf. concave,	Caen.
Monheim.	Concavo-convex,	Geosaurus,		Plesiosaurus,	,,	Lyme.
Stonesfield and Tilgate.	Superficially concave,	Megalosaurus,	Ascending to	Ichthyosaurus,	Deeply concave,	Lyme.
Tilgate.	Superficially concave,	Hylæosaurus,		Paleosaurus,	,,	Durdham
Thuringia.	Doubtful,	Monitor,	Sauroid Fishes.	Thecodontosaurus,	,,	,,

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The Rev. Mr. Clarke stated the existence of two springs on the north side of Hales Bay (part of Poole Harbour), whose flow is constant, and whose temperature is also constant, day and night, summer and winter, at $51\frac{1}{2}$ degrees of Fahrenheit. The line of junction of these springs is parallel to the elevated vertical range of chalk which runs through the Isles of Wight and Purbeck.

Mr. Boscawen Ibbotson exhibited two models constructed by himself; one of the Principality of Neufchatel, copied from the map of Osterwald, and on the scale of $\frac{1}{2}$ an inch to the mile, and the other of $\frac{1}{2}$ a mile of the Undercliff in the Isle of Wight, on the scale of 3 feet to 1 mile.

A letter from Dr. Mantell was read, accompanying Drawings by Mr. Dinkel of various Reptilian Remains.

A Drawing was exhibited by Mr. Murchison of a remarkably large unknown Fish in the possession of the Rev. Mr. Noble from the Old Red Sandstone of Clashbennie in Fifeshire;* communicated by Mr. J. Robinson, Sec. R.S.E.

* A drawing of this fish having been forwarded to M. Agassiz, he has named it *Holoptychus Nobilissimus.* A figure and description of it will appear in Mr. Murchison's new work.

A letter was read from Dr. Traill referring to some specimens of fossil fishes from the Caithness schist of the Island of Pomona (Orkneys), and from Clashbennie, which were exhibited to the Meeting.

A Classification of the old Slate Rocks of the North of Devonshire, and on the true position of the Culm Deposits in the central portion of that County. By Professor Sedgwick *and Mr.* Murchison.

The authors began by observing, that this was a mere outline of a more detailed memoir on the physical structure of Devonshire, which they were about to lay before the Geological Society of London. In the published geological maps of that county the whole system of the older slate rocks was represented under one colour, without any attempt at subdivision; and one colour also represented different limestones, without any discrimination. The object of the authors was to remedy these defects, to ascertain and represent the true position of the successive deposits and their natural subdivisions, so as to compare them with corresponding deposits in other places. They also wished to determine the exact place of the remarkable carbonaceous deposits of central Devon, which had been previously regarded as belonging to one of the lowest portions of the grauwacke formation.

A section was exhibited of part of that county, from the north coast to one of the granite peaks of Dartmoor immediately south-west of Oakhampton.

In the ascending order this section exhibits—

1. A system of slaty rocks, containing a vast abundance of organic remains, generally in the form of casts. These rocks sometimes pass into a fine glossy clay slate, with a transverse cleavage; sometimes into a hard quartzose flagstone, not unusually of a reddish tinge; sometimes into a reddish sandstone, subordinate to which are beds of incoherent shale. In North Devon they are very rarely so calcareous as to be burnt for lime, but in South Devon rocks of the same age appear to be much more calcareous.

2. A series of rocks characterized by masses of hard, thick-bedded red sandstone, and red, micaceous flagstone, subordinate to which are bands of red, purple, and variegated shales. The red colour occasionally disappears, and the formation puts on the ordinary appearance of a coarse, silicious grauwacke, subordinate to which are some bands of imperfect roofing slate. In this series are very few organic remains. It is several feet in thickness, occupying the whole coast from the west end of the Valley of Rocks to Combe Martin.

3. The calcareous slates of Combe Martin and Ilfracombe, of very great aggregate thickness, abounding in organic remains, and containing in a part of their range at least nine distinct ribs of limestone burnt for use. This limestone is prolonged into Somersetshire, and appears to be the equivalent of that on *the flanks* of the Quantock Hills.

4. A formation of greenish and lead-coloured roofing slate of great thickness, and occupying a well-defined zone in North Devon, its upper beds alternating with and gradually passing into a great deposit of sand-

stones of various colours and micaceous flagstones. These silicious rocks alternate with incoherent slates, and are in some places surmounted by great masses of red unctuous shale, which, when in a more solid form, generally exhibit cleavage oblique to the stratification.

5. The lower part of the Silurian system rests conformably on the preceding, and on the north-western coast, near Barnstaple, containing subordinate beds of limestone. In its range towards the eastern part of the county it gradually thins off, but its characters are well preserved, and it contains some characteristic organic remains.

6. The carbonaceous system of Devonshire ranges in a direction east and west across the county, in its southern boundary so close to Dartmoor, that its lower beds have been tilted up and altered by the granite. It occupies a trough, the northern border of which rests partly in a conformable position upon the Silurian, and partly upon older rocks, probably of the division No. 4. Its southern border also rests on the slate rocks of South Devon *. It everywhere exhibits a succession of violent contortions. In some places it is overlaid by patches of the Green Sand formation, and west of Bideford by conglomerates of the New Red Sandstone. The lowest portion of this vast deposit is generally thin-bedded, sometimes composed of sandstone and shale, with impressions of plants, sometimes of indurated compact slate, containing *wavellite*. These beds are surmounted by alternations of shale and dark-coloured limestone with a few fossils. Subordinate to these, on the western side of the county, are thin veins and flakes of culm or anthracite; but this is wanting on the eastern side, and the calcareous beds are more expanded. The higher beds of this deposit are well exhibited on the coast west of Bideford. These often contain impressions of vegetables.

Though in a state of greater induration than the ordinary coal-measures of England, and even in many places destitute of coal, these beds do not differ from the great productive coal or culm field of Pembrokeshire. The authors consequently concluded, that from the order of superposition,—from mineral structure—from absence of slaty cleavage peculiar to the older rocks on which it rests—and from the specific character of its organic remains—this deposit may without hesitation be referred to the regular carboniferous series.

In the course of the details a remarkable elevated beach was alluded to, occupying two miles of coast, on the north side of Barnstaple Bay, a more special account of which has since been prepared for the Geological Society.

On the Site of the Ancient City of Memphis. By the Marquess Spineto.

The author read a paper, entitled, "A Report of the Attempts made to ascertain the Latitude of the Ancient City of Memphis:" he considers the site of this city as having been in the present bed of the Nile, in latitude 29° 46′ north, and longitude 31° 30′ east from Greenwich.

* The authors have since read a Memoir before the Geological Society, on the general structure of Devonshire, in which the age of the strata of South Devon is pointed out.

ZOOLOGY AND BOTANY.

An Account of the Organ of Voice in the New Holland Ostrich. By JAMES MACARTNEY, *M.D., F.R.S., &c.*

Those who have visited zoological gardens containing the ostriches of New Holland, must have remarked the very singular sound produced by these animals; it is a species of grunt, but much softer than that of the hog, and involving the vibration of so large a volume of air, that the persons standing near the bird may feel a tremor communicated to their own bodies. Having had an opportunity of examining the structure of the animal, Dr. Macartney found that there exists a mechanism amply sufficient for the production of the extraordinary sound above mentioned. In the middle of the trachea there is a large opening, directly communicating with a membranous cell of very considerable extent, which is placed under the skin of the neck. There is no peculiarity of structure at the bifurcation of the air tube into the two bronchi, and this part is only furnished with the two long muscles usually found in the organ of voice in birds when it possesses the simplest mechanism; consequently the peculiar sound belonging to the New Holland ostrich is entirely occasioned by the reverberation or resonance produced in the membranous bag connected with the front of the trachea.

Several birds of the duck and merganser genera are known to have the voice modified, and the volume of tone increased by dilatations or convolutions of the trachea. It is by a convolution of this kind that the land rail also is enabled to utter the creaking sound for which this bird is so remarkable. The neighing of the horse and the hideous cry of the ass are effected by the addition of some membranous chambers situated near the exit of the air from the wind-pipe. In some monkeys there is a membranous bag communicating with the top of the trachea, and the howling baboon has chambers composed of bone conjoined with the larynx. The bull-frog, which is heard to so great a distance, is provided with reverberating pouches; but Dr. Macartney is not aware of any example in the class of birds, except the New Holland ostrich, where the organ of voice is furnished with a membranous bag for augmenting the sound, nor any instances amongst the other classes of animals in which pouches are connected with the *middle part* of the trachea. The structure of the organ for producing sound in the New Holland ostrich is therefore considered to be peculiar to that bird.

As the animal from whence these observations were made was a male, the author was inclined to suppose that the peculiarity of voice did not belong to the female, which is usual in birds; but he has since ascertained that it belongs to both sexes, which is a still further deviation from common rule.

On the Foot of the 'Two-toed' Ostrich (Struthio Camelus). *By* HENRY RILEY, *M.D.*

In this communication Dr. Riley showed that the number of toes in the foot of this bird was the same as that of the Cassowaries and the Nandua or *Struthio Rhea*. The difference observable is, that in *Struthio Rhea* the internal toe is fully developed, while in the 'two-toed' ostrich it is in a rudimentary state, and completely covered and concealed by the integuments of the foot. In the specimen exhibited (a young bird) there was a well defined condyle on the inner side of the phalangic extremity of the tarsal bone, smaller but similar in all other respects to the other two heads or condyles, serving the purpose of receiving the first phalanges of the two toes already described by naturalists. Articulated with this condyle was a rudimentary toe about an inch and a half in length, and consisting of two phalanges; the first or tarsal phalange completely ossified, one inch long, cylindrical, and of the calibre of a crow's quill. It was articulated with a second phalange, not yet ossified, cartilaginous, and barely half the length of the preceding.

On the Manati or Cowfish of the Inland Waters of Guiana. *By* JOHN HANCOCK, *M.D.*

This communication contained the author's observations on the natural history of the Manati, descriptions of the principal points of its remarkable organization, and habits of life.

Mr. CURTIS exhibited some specimens of the terminal shoots of a Pinus which had been attacked by the *Hylurgus piniperda*, and made some remarks upon the habits of this insect.

ROBERT BALL, Esq. of Dublin, exhibited for the purpose of eliciting information, several crania of a large species or rather genus of Seal, which had hitherto unaccountably escaped the notice of naturalists as a native animal, though very common on the coast of Ireland.

Professor NILSSON of Lund pronounced the crania to belong to the *Halichœrus griseus* (synonymous with *Phoca Gryphus* of Fabricius), found in the Baltic, North Sea, and Iceland, and recorded as the type of a new genus in his *Fauna Suecica*.

Mr. BALL also exhibited the skull of a seal taken on the coast of Sligo, agreeing with the principal descriptions of *Phoca Vitulina*, and much less common than the foregoing on the shores of Ireland; and Doctor RILEY produced the skeleton of a seal captured in the Severn, very distinct from the preceding (though under the same denomination). Professor NILSSON stated the former to be *Phoca variegata*, and the latter *Phoca annellata*, which with *P. barbata* had long been confounded under the name of *P. Vitulina*.

On Aranea avicularia. *By* S. ROOTSEY, *M.D.*

On the Probability that some of the early Notions of Antiquity were derived from Insects. By Rev. F. W. Hope.

In this essay the author has endeavoured, by the aid of the knowledge now attained concerning the natural history of insects, to explain the origin of many remarkable and erroneous opinions prevalent among ancient nations, such as equivocal generation, the transmigration of souls, &c.

Notice of Sixteen Species of Testacea new to Scotland. By Mr. Forbes.

Abstract of Dr. Pritchard's Views of the Criteria by which Species are to be distinguished in Zoology and Botany. By W. R. Carpenter, *Esq.*

On the Means of Preserving Animal and Vegetable Substances. By James Macartney, *M.D., F.R.S., &c.*

When dead bodies were obtained with great difficulty for dissection, Dr. Macartney has preserved them in a state quite fit for the purpose upwards of two months before the time they were wanted, by injecting the arteries so forcibly that the cellular system received a part of the fluid. The compound used for this purpose was a concentrated solution of equal parts of alum, nitre, and common salt in water, and an equal quantity of proof spirit, to which the essential oil of lavender or of rosemary had been added in the proportion of ℥ to a quart of the spirit. When dead bodies have been thus prepared they are rendered incapable of the putrefactive process; they remain with an agreeable odour until they dry up or become mouldy, which may not take place for three or four months.

When it becomes an object to preserve the whole body or a portion of it in a dried state, the injection above mentioned, either with or without the salt, according to circumstances, is to be used. The cuticle is then to be removed by scalding with hot water, and the surface having been washed over with the brown or impure pyroligneous acid, the preparation is exposed to dry air.

Animal substances thus preserved on becoming dry acquire great hardness, and shrink but little; they appear to be *perfectly* imperishable, and more capable of resisting all external influences than the mummies of Egypt.

If the injection be made with the salt, the forms fade so little that the resemblance of the original parts is retained, and if the preparation be coated over with a solution of wax in any of the essential oils, (which is found to be the best security against the exudation of the salt,) the part possesses considerable flexibility and softness.

The empyreuma of the pyroligneous acid operates more suddenly and effectually than the smoke of burning wood, but in the same manner: thus, fish wiped over with it and hung up to dry, in a very short time acquires *all* the flavour and appearance of that cured by wood smoke, and hams or bacon washed over with the pyroligneous acid resemble those from Westphalia. For every purpose of preser-

vation Dr. Macartney has found this acid in the impure state quite as effectual as the creosote.

Some very curious examples have been met with in Ireland of entire bodies being preserved in bogs very perfectly for a period probably amounting to many centuries. One of these bodies, in the possession of the Royal Dublin Society, was clothed with an undressed skin only, fastened by a rude skewer in front, a national dress of which we have no account either by history or tradition. Another body has been more lately found eighteen feet under the surface of a bog in the county of Roscommon. It appeared to have belonged to a female of rank; the dress was injured in taking it up, but the hair was tastefully arranged, and ornamented by a pin. Her shoes were thin and nicely made, with only one seam at the heel, a method of construction which Dr. Macartney believes is only met with in Eastern nations. Some bones which had been taken from a bog, and are in the author's possession, exhibit a very curious change of composition, as if they were converted into wood, which appearance they retain even after being burned. (Specimens shown.)

The different essential oils have great powers in preventing putrefaction of animal substances, and also of destroying the vegetable mould which forms on the surface of vegetable infusions and other fluids. Mr. Carlile has employed for preserving animal jelly or size a few drops of the essential oil of cloves and of rosemary with complete success. No animal matter goes sooner into putrefaction than size, yet it has been preserved perfectly sweet for more than a year by the addition of a very small quantity of essential oil: this fact appears very important to scene painters and all artists using what are called body colours. Dr. Macartney has likewise used essential oils to prevent the mouldiness of paste and of solution of gum arabic.

In preparing the dried skins of quadrupeds it is customary to besmear the inner surface of the skin with an arsenical paste, or with a solution of corrosive sublimate. Independently of the objection which exists to the employment of poisonous substances, it has been found that these means have not been always effectual in protecting the external surface of the skins from the attacks of insects. The following is the process which Dr. Macartney has made use of: the skin in the first instance is immersed for two or three days in a concentrated solution of alum and nitre, which has the effect of partially tanning it; next, both surfaces of the skin are wetted with the impure or brown pyroligneous acid; this hastens the drying, and when the skin is completely dried it becomes exceedingly hard, and whether from this circumstance, or from the presence of the empyreuma, it is found that insects of any description are not disposed to attack those so prepared. If any stain remain on the hair it may be removed by brushing the surface with camphorated spirits.

It is known to botanists that it is impossible to preserve by the usual means the forms of massy or succulent plants; in order to effect this object Dr. Macartney has employed a method which exceeded his expectations; it consists in dipping the flower fresh pulled into

a mixture of the finest plaster of Paris and water, made about as thin as milk, or by coating the parts of the plant carefully with this mixture by a camel-hair brush: the plant on drying within this thin shell of plaster is easily detached, leaving the forms of the stamina, pistils, and petals in their natural position, with very little change of colour. Flowers thus preserved retain their peculiar odour for years, from which last circumstance it appears probable that this mode of drying vegetable productions would be found very valuable if employed for medicinal plants, roots, or fruits.

On the Longevity of the Yew, and on the Antiquity of Planting it in Churchyards. By J. E. Bowman, *Esq.*

Being curious to ascertain how far the reputed longevity of the yew would be sustained by an examination of the annual rings of its trunk, and how far De Candolle's average standard of increase at different periods of its growth was correct, the author measured the trunks of 18 yews now standing in the churchyard of Gresford in North Wales, which were planted out in 1726, and found their average diameter to be 20 inches or 240 lines. By comparing these with the dimensions of others whose ages are also known, he came to the conclusion that for yews of moderate age, and where the circumference is less than six feet, at least two lines or $\frac{1}{6}$th of an inch of their diameter should be allowed for annual increase, and even three lines or more if growing in favourable situations. De Candolle says this tree increases little more than one line in diameter annually during the first 150 years, and a little less than one line afterwards, and in very old specimens he considers their age to be at least equal to the number of lines in their diameter. This average is too high for young yews, and, as will presently be seen, too low for old ones.

The author described a noble yew in Gresford churchyard whose mean diameter is eight feet six inches or 1224 lines, and whose age, by De Candolle's method, would be as many years. Sections taken from different sides of its trunk contained as follows:

Average number of annual rings per inch counted on the horizontal plane............	On the north side..	43
	On the south side..	46
	On the S.W. side..	15

giving a general average of $34\frac{2}{3}$ rings in an inch of the diameter. Assuming that this yew, when 120 years old, had a diameter equal to the average of the 18 already mentioned, and among which it grows, and that it continued to increase in the same ratio up to 150 years, and also making additional allowance for an intermediate rate of increase between 150 and 250 years, we arrive at the following result: at 150 years old its diameter would be 25 inches, at 246 years old 33 inches, leaving five feet nine inches of the diameter for subsequent increase, the radius of which, at 34 rings to the inch, would contain 1173 rings or years' growth. To this add 246, and its present age will be 1419 years.

A still greater yew in Darley churchyard, Derbyshire, having a mean diameter of nine feet five inches, was next described. Sections taken

from its north and south sides gave 44 annual rings in the inch, so that its radius would contain 2486 such rings, supposing them of equal thickness throughout; but making the same deductions as before, its present age may be estimated at about 2006 years.

This examination shows the Gresford yew to be about 200, and that at Darley about 650 years older than De Candolle's standard of one line per annum of the diameter would indicate, and consequently that for old trees his average is too low. It also shows that the Darley tree, with a greater diameter than the other of only 11 inches, is 587 years older, the excess arising from the extreme thinness of its annual deposits. No precise rule can therefore be laid down, and actual sections must be resorted to if anything like accuracy be required. Even this plan is liable to errors, unless sections from different sides of the tree be obtained, owing to the great and constantly recurring inequality in the thickness and parallelism of the rings. The same ring often alternately swells out and contracts several times in the course of its circuit round the trunk, and groups or fascicles of rings also do so as if by common consent, while other neighbouring series or individual rings, both within and without, will be thickest where the first were thinnest, and *vice versâ*. Other sources of error are also pointed out.

Mr. Bowman considers the custom of planting the yew in churchyards to be of very high antiquity, anterior even to the introduction of Christianity. It is well known that this tree was used by our Pagan ancestors as a substitute for the cypress, both in religious rites and to place upon the graves of their deceased friends; it was indeed considered scarcely less sacred than their temples near which it was planted. On their conversion to Christianity these temples were not destroyed, but by an express order from Pope Gregory were converted into Christian churches, the better to reconcile them to the change. For the same reason the sacred yew remained unmolested.

Abstract of Observations on the Marsiliaceæ. By G. Lloyd, *M.D.*

Finding in authors many contradictory statements on the nature of the organs of reproduction in this small but interesting order of plants, and having last year, for the first time, had an opportunity of examining *Pilularia globulifera*, the only British species (since Isoetes is transferred to the Lycopodiaceæ), Dr. Lloyd was induced to endeavour to ascertain their true nature.

Without going into a lengthened detail of the structure of the involucre and its contents, it is necessary to state that when opened it is found to contain two distinct kinds of seed-like bodies, differing in size, shape and structure, the larger being the true seeds, and the smaller appearing to perform an office similar to that of the anthers of phænogamous plants. The smaller bodies make no discernible attempt at germination under any circumstances. The seeds of Pilularia germinate when taken from the involucre previous to its natural bursting, and when entirely separated from the smaller bodies or granules; so that if any impregnation be essential to the perfecting of the seed, it must take place within the involucre, and not after dispersion in water, as some

have supposed. To determine the manner of germination, some seeds were placed in water in watch glasses, seeds alone, and seeds with granules, in separate glasses, and in a few days the seeds appeared swollen about the apex, which became of a blackish brown colour, and in a few days more a green point presented itself in a direction vertical to the axis of the seed and became a leaf. The leaf having attained about half an inch in length a white radicle appeared in the opposite direction. When the root had grown about half an inch the young plants all died, probably from exposure to too much light, and from being deprived of other advantages which soil might afford. Suspecting this might be the cause, a glass vessel was nearly filled with mud and water, which was covered by a bell glass, and a number of seeds placed on the surface of the mud and others buried a little below: germination soon commenced, but in this experiment the first leaf proceeded at right angles to the axis of the seed. The leaf invariably appeared before the radicle. In about a week a second leaf and radicle, and again a third appeared, with a rudiment of an horizontal stem, proceeding from the point of union between the first leaf and root. The seed or rather the external covering remained attached to the plants for many weeks. The number of leaves and roots previous to the appearance of the stem is uncertain in different plants. The first leaf is perfectly straight from its first commencement, but all succeeding leaves are coiled after the manner of the fronds of ferns.

The plants obtained from the latter experiment are still growing, though indicating no signs of fructification at present.

The embryo in all cases proceeds from one determinate point at the apex of the seed, which is plainly discernible in the seed in all its stages of development, at first in the shape of a minute conical point, gradually contracting and flattening; and when the seed is matured it appears like a circular opening closed by minute converging teeth, through which the seminal leaf protrudes. The circulation of the sap seems to be carried on chiefly by endosmose and exosmose, as the substance of the stems and leaves consists for the most part of oblong cells of various sizes, their extremities being closed; but in the centre of both stem and leaf may be observed a bundle of vessels of minute dimensions which appear to be ducts. No spiral vessels could be detected. Professor Lindley has noticed ducts in Marsilia. The development of the seminal leaf in Pilularia before the radicle is analogous to the germination of some of the Cyperaceæ, as, according to Mirbel, in *Scirpus sylvaticus*, &c. The habit of this plant also resembles some of the species of that order. When it is considered that so many of the essential characters of the cellulares do not apply to the Marsiliaceæ, as in the plant in question, the embryo proceeding uniformly from a determinate point of the seed, the stems and leaves being vascular, and no other order of the cellulares having a true stem or so perfect an organization, it leads to the conclusion that this order is intermediate between the monocotelydons and the cellulares, or at least first among the latter, as Mirbel and some other continental botanists have placed it.

Abstract of a Paper on Alcyonella Stagnorum. *By* THOMAS PRIDGIN TEALE, *of Leeds.*

In this paper it was stated that from August to November, 1835, the Alcyonella was found in great abundance in a pond near Leeds, having never previously been observed in that district. It occurred in masses of considerable size, incrusting stones, leaves, twigs, earthenware, &c. The author described the anatomical peculiarities of the polype, digestive apparatus, and reproductive system.

The paper was illustrated by drawings, and numerous specimens, and preparations in spirit.

A more detailed account of the structure, habits, and literary history of this zoophyte was read by Mr. Teale before the Leeds Philosophical and Literary Society, and is published in the fasciculus of Transactions of that Society.

The animal was supposed to be new to Great Britain, unless it be proved, as maintained by Raspail, that Plumatella and Cristatella are varieties of Alcyonella.

Mr. MACKAY read a communication he had received from John Nuttall, Esq., of Tittour, county of Wicklow, "On the management of the Pine tribe," in which he stated that having observed almost all the plants of *Pinus sylvestris* and other species, when planted in a light clay slate soil on exposed situations, grow too rapidly, or out of proportion to their rooting, and thereby became *windwaved*, and that those which by accident had lost their leaders took a strong hold of the ground, he commenced a series of experiments as follows. In the spring, when the buds were fully developed, he went over those that were suffering from the foregoing causes, and broke off all the buds except those on short branches. By this process their upward growth is checked for a year, the trunk increases in bulk, and the plant roots much more freely than if the shoots had been allowed to grow. New buds are formed during the summer, and in the following spring these plants present the most vigorous aspect.

The larch he cuts down to a strong lateral branch, on the windward side, when possible. These soon begin to spread their roots, increase in size similarly, and ultimately become choice trees. In some instances he has cut them down a second time, when he found it necessary, and with equally good effect.

On a new and scandent Species of the Norantia, or Ascium of Guiana. By JOHN HANCOCK, *M.D.*

This species of Ascium, which constitutes a remarkable and splendid climber ('Bush rope,') in the forests of Guiana, was minutely described.

Notice of Experiments, now in progress at Oxford, on the Effects produced by Arsenic on Vegetation. By C. DAUBENY, *M.D., Professor of Botany, Oxford.*

Dr. Daubeny was led to undertake these experiments from having

received a communication from Mr. Davies Gilbert, in which he stated that there was a district in Cornwall where the soil contained a large proportion of arsenic; and that no plants could grow in it except some of the Leguminosæ. By analysis, this soil yielded him about fifty per cent. of arsenic, in the form of a sulphuret; the rest being composed principally of sulphuret of iron and a little silica. He had already ascertained that a little of the sulphuret mixed in soils produced no injurious effect on *Sinapis alba*, barley, or beans; and that they flowered and seeded freely when grown in it. Although the want of solubility in the sulphuret might be assigned as a reason for its inactivity, yet it was certainly taken up by water in small quantities, and imbibed by the roots of plants. Upon watering them with a solution of arsenious acid he had found that they would bear it in larger proportions than was presupposed.

On Caoutchouc. By Professor Royle.

Professor Royle stated that he had been induced to draw up the substance of the present communication in consequence of a conversation which he had lately held with the director of an extensive establishment for the manufacture of this substance into various articles of commerce, from whom he learned that the demand at present exceeded the supply. Professor Royle asserted that, in the East, there might be any quantity of the article procured from a great variety of plants, if the natives could only be induced to collect it with sufficient care. The South American caoutchouc is generally collected with so much greater care than that from the East Indies that it bears a very much higher price in the market. That from the latter country is of excellent quality, but generally much mixed with a considerable quantity of dirt, bark of the tree, and other extraneous matter. Professor Royle then enumerated several of the uses to which caoutchouc is now applied, and stated that the East Indian kind, from its great impurity, can only be used for the purposes of distilling from it the volatile spirit caoutchoucine. At the present time, the article from the East is selling at 2*d.* per pound, whilst that from Para fetches from 2*s.* 6*d.* to 3*s.* per pound. It is very remarkable that a substance so incorruptible in water, and so insensible to a variety of chemical re-agents, should have remained so long unknown in Europe. Professor Royle then recapitulated the chief circumstances of its early commercial history, and the method employed for procuring and preparing it. The substance is probably also produced in the southern parts of China, and is now exported from the island of Singapore. The Mauritius, Madagascar, Java, Penang, were then instanced as other localities from whence caoutchouc was obtained, and reference was made to the manner in which it was prepared in the latter country. By experimenting upon other species of the same families as those which were known to contain caoutchouc, it would probably be found that the list of plants from which it could be obtained might soon be much increased. Professor Royle then mentioned those families in which it had already been observed to exist in greater

or less proportion. These were, the Cichoraceæ, Lobeliaceæ, Apocyneæ, Asclepiadeæ, Euphorbiaceæ, Artocarpeæ. It is remarkable that many plants of the families which yield caoutchouc are characterized by the strength and tenacity of their fibre, and in tropical countries birdlime is prepared from plants of the same families. These observations, connected with the fact that the silkworm feeds on several plants of the families which yield the caoutchouc, though otherwise little allied to each other, induced Mr. Royle to suppose that this substance might possibly form a necessary ingredient in those plants upon which only they can feed, and that it was in some way employed in furnishing the material from which the tenacity was given to their silk. This induced him to inquire whether caoutchouc existed in their favourite food the mulberry, and a friend having analysed the juices of this plant, substantiated the validity of his conjecture.

On the Acceleration of the Growth of Wheat. By G. WEBB HALL, *Esq.*

The usual period required for the growth and maturity of wheat (eight, ten, or even more months,) might, according to the results of experiments conducted by Mr. Hall, be considerably abridged. By the use of particular seed, planted in a peculiar situation, wheat, sown early in March, has been ripened before the middle of August. Mr. Hall is of opinion that, in consequence of the transmission of special qualities from plants to their seeds, the seeds of wheat which had ripened in five months would be more likely to exhibit a like acceleration than grain taken from plants which had been longer in ripening.

Notice of Crystals of Sugar found in Rhododendron ponticum. *By Professor* HENSLOW.

Some crystalline fragments of pure white and transparent sugar, resembling sugar-candy, and of considerable dimensions, which had been naturally formed in the flowers of *Rhododendron ponticum,* were exhibited by Professor Henslow. There is a minute glandular spot near the base, and on the upper surface of the ovarium, from whence exudes a thick clammy juice, which, on desiccation, crystallizes into the substance here mentioned.

On the Fruits, cultivated and wild, of the Deccan, in the East Indies. By Lieut.-Col. SYKES.

The author stated that they amounted to forty-five cultivated (many of which are found wild also), and twenty-one wild fruits. They were illustrated by many drawings which were formed from careful measures, and had scales of length attached to them. The times of flowering and fruiting were mentioned, and the uses of the various fruits in the arts, in the general œconomy of the people; and, deriving his intelligence from

several ancient Sanscrit works, the author detailed their medical qualities according to the opinion of the Hindus; and enumerated the religious ceremonies and ideas with which the plants and their products were associated. He found the Annona, Anacardium, and Carica in universal cultivation, although they are supposed to be natives of the Western world. He described what he considered to be the original of the Citrus family, as abounding in the wild state as a good-sized tree along the Western Ghauts of the Deccan; and he stated the wild nutmeg to be a noble forest tree at the source of the Beema river. Colonel Sykes gave, also, the names of various fruits in the Mahratta, Sanscrit, and Hindustanee languages; and noticed that, wherever a Sanscrit name was wanting, the probability was that the fruit was not indigenous.

It appeared there were three kinds of mulberry, the species of one of which was unknown; and it was suggested that the Deccan afforded a fine field for their cultivation, and the profitable production of silk.

On Sugar, Malt, and an Ardent Spirit extracted from Mangel Wurzel. By S. Rootsey, *M.D.*

On the Formation of Peat. By Mr. Phelps. (*Illustrated by Specimens.*)

On Imbibition of Prussiate of Potash by Plants. By Dr. Corbet.

Many specimens illustrative of particular subjects in Natural History were presented by Mr. Hope, Mr. Bowman, Mr. Hewitson, Mr. Ball, Dr. Riley, Mr. Yates, Dr. Tyarck, Mr. Mackay, &c. &c.

MEDICAL SCIENCE.

On the Treatment of some Diseases of the Brain. By Dr. J. C. Prichard.

After a general view of the state of knowledge as to the efficacy and *modus operandi* of the remedies and methods of treatment usually employed in these diseases, the author gave the following account of a process adopted in the Bristol Infirmary.

As the means which are within our reach for treating disorders of the encephalon are so circumscribed, it appears so much the more necessary to endeavour to apply in the most efficacious manner such resources as we possess. I am not disposed to believe that any material improvement can be made in the ordinary rules for the use of evacuants or measures of depletion, but I have no doubt that an important advantage may be gained by directing, in a particular manner, the mode of counter-irritation, and it is chiefly with the view of recommending this attempt that I have premised the foregoing remarks. Long ex-

perience has convinced me that the most efficacious way of applying counter-irritation in diseases of the brain is a method not often practised in other places, which has been for many years in almost constant use at the Bristol Infirmary. An objection would probably arise in the minds of those who have not witnessed the application of this remedy on account of its apparent severity. I hope to convince the Medical Section, and through this opportunity to make more general than would otherwise be done, the persuasion that the method of treatment to which I refer is by no means so painful or severe a remedy as it might be supposed to be, and that it greatly exceeds in efficacy all other means by which physicians have attempted to relieve diseases of the brain on a similar principle. The application I recommend is an issue produced either by means of a soft caustic, or what is much better, by an incision over the scalp. The incision is most frequently made in the direction of the sagittal suture, from the summit of the forehead to the occiput. The scalp is divided down to the pericranium. The incision, when that method is used, or the aperture left by the slough, when caustic is employed, is kept open by the insertion of one or two, or in some instances three rows of peas. The discharge thus occasioned is considerable, and it obviously takes place from vessels which communicate very freely with the vessels of the encephalon. It would appear, *à priori*, very probable that an issue in this particular region, just over the sagittal suture, would have a greater effect on the state of the brain than in any other situation, and the result of very numerous trials has abundantly established the fact. I can venture to assert, that in all those cases of a cerebral disease in which counter-irritation is at all an available remedy, an issue of the kind now described is, next to bleeding, by far the most important of all the means which have yet been, or are likely to be discovered. The kinds of cerebral disease in which counter-irritation is beneficial, include, according to my experience, all those complaints which are accompanied by usual stupor or dimitriotical sensibility, excluding all affections, attended by over-excitement, such as maniacal and hysterical diseases. In the latter, I believe all such measures to be for the most part highly injurious.

A case has lately occurred in my practice at the Bristol Infirmary, which strongly exemplifies the efficacy of the treatment which I have recommended, and which I have fortunately an opportunity of bringing before the Medical Section in the most convincing way. A youth about eighteen came into the Infirmary labouring under complete amaurosis, which had been coming on gradually for a week or ten days before his admission. At that time it had become so complete that vision was entirely lost, and the pupils were totally insensible to light even when the rays of the sun were suffered to fall immediately into the open eyes. At first he was freely and repeatedly bled from the arm and temporal artery, had leeches applied to the scalp, blisters to the nape of the neck, and took calomel so as to render his gums sore. Finding that no effect whatever was produced by these measures, I gave up the expectation which I had at first entertained of his recovering sight, but was resolved to give the remedies a complete trial. I ordered

him to be bled, *ad deliquium.* This took place after a small quantity of blood had flowed from his arm while he was in an erect posture. After a few days, he was still perfectly dark: an incision was now made over the sagittal suture from the forehead to the occiput. It was filled with peas. In three or four days, precisely at the time when suppuration began to take place, the patient declared that he perceived light, but was scarcely believed, since the pupils were still widely dilated and quite insensible to a strong light. In the course of a few days it was quite evident that he saw; he could tell when two or three fingers were held up. For some weeks the iris was still quite irritable, though vision had become in a great degree restored.

The subsequent treatment of the case consisted chiefly in occasional leechings, purging, and low diet: when the issue healed, which was not till it had been kept open for some months, a seton in the neck was substituted. Under this treatment the case has terminated in a complete recovery of the blessings of sight.

Abstract of an Unpublished Work on Tetanus. By James O'Beirne, *M.D. Surgeon Extraordinary to the King, &c. &c., Dublin.*

Dr. O'Beirne commenced by showing the very extensive opportunities which he had enjoyed, both in his military and civil life, of observing and treating this most fatal and mysterious disease, the laborious research, and the patient and strictly clinical observation which he had devoted to the investigation of the subject from a very early period, particularly for the last fifteen years. He then repudiated all other species of the malady than the traumatic and the idiopathic, to the latter of which he applied the term "atraumatic," as being more expressive and scientific. He admitted no such varieties as trismus, tetanus, rectus, or pleurosthotonos, recognising only opisthotonos and emprosthotonos. Instead of dividing the latter varieties into acute and chronic, he proposed dividing them into the peracute, acute, subacute, and chronic. He agreed with most authors upon the causes, but considered certain unknown electrical states of the atmosphere as the most general and operative. The extreme periods of the accession of the traumatic species, he stated to be the fourth and seventeenth days from the infliction of the wound, and also stated that it never attacks after the cicatrization of a wound, or during an inflamed state of a wound, and that it does not supervene upon burns, scalds, military flogging, or other injuries of the skin which do not penetrate the fasciæ or the muscles. He asserted the general character of the disease to be the same in all climates and countries, and to have been the same in all ages. He denied the existence of any premonitory symptoms, and stated that the disease is never ushered in or attended by cutaneous eruptions, or by any febrile symptoms; that it has no tendency whatever either to crisis or to sudden disappearance; and that recovery invariably takes place slowly, the period varying from eighteen days to seven, eight, and even nine weeks. After making these and many other novel statements respecting the attack, course, and termination of the malady, he described,

with great minuteness, all the phænomena of the disease, and the general laws by which it is regulated, in order to show what constitutes genuine tetanus; and, amongst other interesting facts, he mentioned that he has seen the peculiar tetanic expression of the face retained for fourteen years. (Here a lithographic representation of the face of a patient, during and between the tetanic paroxysms, was exhibited to the section).

He considered the singular alteration of the countenance to be the only true pathognomonic sign of the disease, and declared the phænomena and laws of this affection to be more uniform and definite than those of any other. He considered that there were many strong reasons for believing that the degree of general suffering which the patient endures, is by no means so great as is universally supposed, or as the external and very frightful characters of the malady would seem to indicate. He then stated, that, after post-mortem examinations made in several cases of opisthotonos, and which he knew to be genuine, the only morbid or abnormal appearances were great distension of the cæcum and colon, and rigid contraction of the rectum; but that in cases of emprosthotonos, either the heart or lungs, or both of these organs, were always found more or less diseased. He next showed the extraordinary extent to which the disease has been confounded with injuries of the temple, face, mouth, and pharynx, and with hysteria, rheumatism, spinal irritation, spinal arachnitis, cynanche tonsillaris, and a peculiar affection to which he gave the name of, "pseudotetanus." He also showed how satisfactorily the knowledge of such mistakes explained numerous perplexing circumstances relating to the pathology and treatment of the disease.

Dr. O'Beirne then described the difficulties which he had encountered in founding a correct pathology of tetanus, the means and steps by which he was enabled to overcome those difficulties, and ultimately to arrive at a satisfactory solution of those long contested and unsettled points, the seat and nature of the malady. He placed its seat in the substance of the anterior columns of the spinal marrow, and showed that its nature is purely functional, and consists in either an accumulated or a peculiarly intense condition of the motific principle residing in the anterior spinal columns or pyramids, and perhaps their prolongation to the optic thalami and striated bodies. But he considered that an affection of the origin of the pneumogastric nerves is superadded in cases of emprosthotonos. The remedial agents which he employs he stated to be tobacco, the gum-elastic tube, and croton oil, and then mentioned the rules which should guide their employment, and without a knowledge of which life might be sacrificed at the very moment of success. He next laid before the Section a tabular view of twenty cases treated upon his plan, from which it appeared that eleven had terminated in perfect recovery. From this document it also appeared that, of the remaining nine fatal cases, one would have been successful if the use of the tube had been known at the time, while in six others it was found that the patients had laboured under organic disease of either the heart or the lungs for a long period previous to

the attack of tetanus. He then asserted this amount of success to be far greater than had ever been obtained, and that the uncomplicated disease is no longer to be considered as either incurable or mysterious. Dr. O'Beirne concluded by stating that Mr. Walker, a veterinary surgeon of Dublin, to whom he had communicated his mode of treating the disease in man, had succeeded in recovering seventy-three horses affected with tetanus.

On the Cause, the Prevention, and the Cure of Cataract. By Sir D. Brewster, *F.R.S., &c.*

Having submitted to the Physical Section an account of a singular change of structure produced by the action of distilled water upon the crystalline lens after death, Sir D. Brewster was desirous of communicating to the medical section some views which this, and previous observations, have led him to entertain respecting the cause and the prevention and cure of cataract.

"The change of structure to which I have referred consists in the development of a negative polarizing band or ring between the two positive rings nearest the centre of the lens; the gradual encroachment of this new structure upon the original polarizing structure of the lens; and the final bursting of the lens after it had swelled to almost a globular form by the absorption of distilled water.

"As the crystalline lens floats in its capsule there can be no doubt that it is nourished by the absorption of the water and albumen of the aqueous humour, and that its healthy condition must depend on the relative proportion of these ingredients. When the water is in excess the lens will grow soft, and may even burst by its over absorption, and when the supply of water is too scanty, the lens will, as it were, dry and indurate, the fibres and laminæ formerly in optical contact will separate, and the light being reflected at their surfaces, the lens will necessarily exhibit that white opacity which constitutes the common cataract.

"This defect in the healthy secretion of the aqueous humour, as well as the disposition of the lens to soften or to indurate by the excess or defect of water, may occur at any period of life, and may arise from the general state of health of the patient; but it is most likely to occur between the ages of 40 and 60, when the lens is known to experience that change in its condition which requires the use of spectacles. At this period the eye requires to be carefully watched, and to be used with great caution; and if any symptoms appear of a separation of the fibres or laminæ, those means should be adopted which, by improving the general health, are most likely to restore the aqueous humour to its usual state. Nothing is more easy than to determine at any time the sound state of the crystalline lens; and by the examination of a small luminous image placed at a distance, and the interposition of minute apertures and minute opake bodies of a spherical form, it is easy to ascertain the exact point of the crystalline where the fibres and laminæ have begun to separate, and to observe from day to day whether the disease is gaining ground or disappearing.

"In so far as I know, cataract in its early stages, when it may be stopped or cured, has never been studied by medical men; and even when it is discovered, and exhibits itself in white opacity, the oculist does not attempt to reunite the separating fibres, but waits with patience till the lens is ready to be couched or extracted.

"Considering cataract, therefore, as a disease which arises from the unhealthy secretion of the aqueous humour, I have no hesitation in saying that it may be resisted in its early stages, and in proof of this I may adduce the case of my own eye, in which the disease had made considerable progress. One evening I happened to fix my eye on a very bright light, and was surprised to see round the flame a series of brightly coloured prismatic images, arranged symmetrically and in reference to the septa to which the fibres of the lens are related. This phænomenon alarmed me greatly, as I had observed the very same images in looking through the lenses of animals partially indurated, and in which the fibres had begun to separate. These images became more distinct from day to day, and lines of white light of an irregular triangular form afterwards made their appearance. By stopping out the bad parts of the lens by interposing a small opake body sufficient to prevent the light from falling upon it, the vision became perfect, and by placing an aperture of the same size in the same position, so as to make the light fall only on the diseased part of the lens, the vision entirely failed.

"Being now quite aware of the nature and locality of the disease though no opacity had taken place so as to appear externally, I paid the greatest attention to diet and regimen, and abstained from reading at night, and all exposure of the eyes to fatigue or strong lights. These precautions did not at first produce any decided change in the optical appearances occasioned by the disease; but in about eight months from its commencement I saw the coloured images and the luminous streaks disappear in a moment, indicating in the most unequivocal manner that the vacant space between the fibres or laminæ had been filled up with a fluid substance transmitted through the capsule from the aqueous humour. These changes took place at that period of life when the eye undergoes that change of condition which requires the use of glasses, and I have no doubt that the incipient separation of the laminæ would have terminated in confirmed cataract had it not been observed in time, and its progress arrested by the means already mentioned. Since that time the eye, though exposed to the hardest work, has preserved its strength, and is now as serviceable as it had ever been.

"If the cataract had made greater progress, and resisted the simple treatment which was employed, I should not have hesitated to puncture the cornea, in the expectation of changing the condition of the aqueous humour by its evacuation, or even of injecting distilled water or an albuminous solution into the aqueous cavity."

On the Nature and Origin of Cancerous and Tuberculous Diseases. By R. CARMICHAEL.

Mr. Carmichael having stated that the averaged mortality in these

islands arising from tuberculous diseases amounts to one-fourth of the entire population, proceeded to describe the appearances of tubercles in the lungs, and entered into a consideration of the prevailing doctrine respecting their nature, viz., that they are inorganizable bodies consisting of lymph of a vitiated character, and analogous in every respect to the depositions which take place in scrofulous tumours near the surface of the body, and that therefore those most influential authorities, Clarke, Carswell, and Todd, insist upon the actual identity of the two diseases. From this opinion Mr. Carmichael altogether dissents, although willing to admit that the scrofulous constitution is above all others most disposed to tuberculous consumption, and argues from the following facts that tubercles are parasitic entozooa, in the possession of independent life, and no further connected with the animal in which they are lodged than that they draw from it the materials of their growth, which they imbibe and assimilate by their own innate powers.

1. Scrofulous tumours are preceded and attended by more or less inflammation, which tubercles *are not*, as is admitted even by those who contend for the identity of the two diseases.

2. Tubercles either present the appearance of grey semi-transparent vesicles, or of round compact granular-like bodies of a medullary appearance, totally unlike the depositions that are formed in scrofulous tumours; but when they are clustered together in great numbers they may be compressed into each other, so as to give the appearance of an extended inorganized substance, and in such a state may be moulded into the form of the parts in which they are found; a circumstance that has afforded an argument not deemed conclusive by Mr. Carmichael in favour of the opinion that the tuberculous substance is nothing more than vitiated lymph or strumous matter.

3. Tubercles *cannot be injected* (as was evinced by the preparations laid before the Meeting), while no one will contend that scrofulous tumours are not easily injected; therefore, as the former have no communication by vessels with the surrounding parts, and as they increase sometimes even to an enormous extent, it is inferred that their production and growth depend upon their internal powers, by which they imbibe nourishment from the surrounding parts.

4. The tuberculous substance, as long as it maintains life, will *not* give the stimulus of an extraneous body, as is exemplified by the facts adduced respecting the *Filia medinensis*, or Guinea worm; but when it dies it causes inflammation and its consequences in the surrounding parts: the softening process then takes place in the tuberculous substance, which (when these bodies are produced in the lungs) is either expectorated by its making its way into the bronchial tubes in the form of a peculiar well known tenacious matter which has neither the properties of pus nor mucus, or it is absorbed, leaving scarcely more behind than the earthy particles it contained, which appear in the consistence of chalk and water, or soft putty, lodged in a shrivelled cartilaginous cyst.

5. Pathologists and chemists agree in the fact that a large proportion of phosphate and carbonate of lime is found in tubercles, and it is

therefore common to find them at their last transmutation changed into a mixture resembling chalk and water, or even into solid calcareous or bony concretions. Now as these substances *are not* found in coagulable lymph, but are furnished in large quantities in the last transmuted state of hydatids (acknowledged animals), a strong argument is thus afforded against the present opinions respecting tubercles, and in favour of those which the author supports.

6. By feeding rabbits on unhealthy diet, in damp places where they are deprived of exercise, hydatids and medullary tubercles will be produced in the course of a few months in the organs of the different cavities. Doctors Jenner and Baron were thus able to produce hydatids, which were afterwards transmuted into solid bodies. Mr. Carmichael by a similar experiment ascertained that medullary tubercles might also be produced; and therefore, though he has no doubt but that tubercles are frequently transmuted hydatids, yet he infers from his experiments that they are also as often found *ab initio* in the medullary solid form.

7. It is only on the principle of the parasitic origin and growth of the tubercle, that we can satisfactorily account for those enormous masses of tuberculous growth found in the abdomen and elsewhere, which *are not connected by vessels with the surrounding parts, are not occasioned by inflammation,* and which *only* destroy the patient by their increase to an extent that interferes with the functions of the organs in which they are imbedded or surrounded.

In a work on cancer, published in 1806, Mr. Carmichael advocated the independent vitality of that disease. At that period he supposed that the entire mass was of zoophytic nature. He has now ascertained that there are two distinct substances in the cancerous mass,—the one medullary, the other cartilaginous. The first he considers to be the true entozooa; the last, which is capable of being injected, is part of the parent animal, and the barrier which it throws out to protect it from the progress of this entozooa. In cancer the great bulk of the morbid growth is cartilaginous; in fungus medullaris and fungus hematodes it is medullary. Hence the more rapid progress and destructive nature of the latter, which may generally be esteemed as constitutional, or owing to some fault in the habit; and hence the ill success attendant upon all attempts to remove the disease by surgical operation.

The author observes: "If my views of these diseases are correct and founded in nature, another, but a lower link will be added to the entozooa, which according to Cuvier belongs to the second class of zoophytes."

The following species may at present be enumerated:

1st. Tubercle of the lungs and other parts, whether commencing in the form of a grey semi-transparent vesicle or of a whitish medullary substance.

2nd. Masses of tuberculous matter in the abdomen, which either commence in the hydatid form, or in that of medullary tubercle; these are called by Dr. Baron tuberculated accretions.

3rd. Fungus medullaris and fungus hematodes.

4th. Carcinoma.

Under these views Mr. Carmichael proceeded to offer some general suggestions on the subject of medical treatment in the diseases discussed, and referred to a work on scrofula which he had published in 1806.

On the Structure of the Teeth, with an Account of the process of their Decay. *By* JAMES MACARTNEY, *M.D., F.R.S., &c.*

It is universally known that human teeth are composed of two substances, one which determines the figure of the teeth, and another superposed on the surface subjected to friction. Anatomists agree in considering the first of these as the production of the peculiar structure called the pulp, and the enamel as the secretion of the capsule or membranous bag which inclosed the pulp, and the rudiments of the proper substance of the teeth. All the other natural forms of osseous matter, whether they be original or provided for reparation, are preceded by a nidus or preliminary tissue, which is either of a gelatinous or cartilaginous nature; for Dr. Macartney has ascertained that the bones of the cranium are produced, like all the others in the body, by the deposition of earthy matter in a cartilaginous substance, which is previously formed between the dura mater and the periosteum of the skull. The teeth therefore in all essential circumstances differ from common bone, and more nearly resemble in their mode of growth, and their natural temporary existence, the external coverings of the body.

The pulps of teeth are known to be very vascular, and so sensible that they are popularly called the nerves of the teeth. When a pulp is successfully injected with size and vermilion, and examined in a soft state, it appears of a pink colour, as if it were stained throughout, instead of deriving its colour from vessels charged with the matter of the injection. In this circumstance it differs from the capsule, which exhibits, after injection, distinct though numerous red vessels. If, however, the pulp be dried on glass, its fine vessels become so apparent, that their arrangement can be easily seen. Dr. Macartney has been enabled to see the disposition of the nerves in the pulp by the same means he has employed for rendering visible the ultimate arrangement of the nervous filaments in the brain. Thus if a section be made of the pulp in a recent state and a solution of alum applied for a few minutes, and the part examined with a lens, a number of white filaments appear at the base of the pulp. These coalesce below the middle, so as to form a whitish cloud, from whence more distinct filaments radiate in great numbers towards the surface of the pulp. This appearance may be considered as a ganglion of the most delicate structure in the nervous system, and fully explains the high degree of sensibility possessed by the pulps of teeth, and also the sympathy which is known to exist between them and the rest of the nervous system.

After discovering the structure of the pulps of the teeth, and comparing it with the inferior degree of organization which belongs to the capsule, Dr. Macartney is disposed to attribute the irritation which so often attends the eruption of the teeth to pressure on the pulp,

rather than to the tension of the capsule, against which opinion the immediate relief obtained by cutting the gum and capsule forms no argument, as this operation would also have the effect of liberating the pulp from pressure. When we contemplate the ultimate structure of the nerves in the pulp, and consider that they are branches of so complex a nerve as the fifth, we see sufficient cause for the numerous morbid feelings and actions which may attend the development of the teeth, and we may admit their connection with this event to the extent supposed by Dr. Ashburner in his ingenious little work on dentition.

In the teeth we have an example of an animal substance resembling the cartilaginous material of common bone, but placed out of the circulation, and apparently carrying on no vital action, yet in immediate contact with a pulp which is perhaps the most highly organized substance in the body, and adhering on the outside without a vascular union to the periosteum which lines the alveola of the jaws, and the vascular structure of the gums, and subject also to a peculiar species of decay, which is neither like the mortification of living structure, nor the putrefactive decomposition of the dead. The destruction of the substance of the teeth by what is improperly called caries, takes place in the following manner, which it is believed has not yet been accurately described by any author. At first a dark green speck is observed on the enamel. When a section is made of the tooth, the enamel at this part appears to have lost its animal substance; it is more porous, has a more opake white colour, and appears as if it were charred by heat. To this change succeeds the first step of decomposition in the proper substance of the tooth, which is marked by a greenish streak leading from the place where the decay began in the enamel, to the nearest part of the cavity holding the pulp. The enamel afterwards breaks down, and is lost where it was first affected, and the fluids of the mouth are admitted more freely to the proper substance of the tooth, which becomes soft, and gradually wears away, until the decay reaches the cavity of the tooth. The pulp is then exposed, and usually inflames, causing one species of toothache. Like all other very delicate tissues, such as the brain and the nerves of vision and hearing, the pulp cannot bear exposure and inflammation without sloughing more or less, and when a part of it is thus lost, it is never repaired, nor properly speaking even healed. The inflammation of the pulp may be excited, and kept up by the slightest external causes, such as contact of foreign bodies or any unusual degrees of either heat or cold. The tooth-ache is frequently produced by secret irritations of the sentient surface of the alimentary canal, or of some other part of the nervous system, and hence it is sometimes removed by an active purge, by baths, or by strong mental impressions.

That the decay of the substance of the teeth is not a vital action, as supposed by Mr. Hunter and others, is proved by the fact of its taking place even more readily in artificial teeth, than in those naturally fixed in the head, whether these artificial teeth be taken from the human subject or made of the teeth of an animal: and that it is produced by

the fluids of the mouth is demonstrated by the decay taking place in those situations where these fluids are longest detained, as between the natural teeth, and most frequently in the back teeth and in those of the lower jaw, or on those parts of artificial teeth where the ligature, wire, or pivots are employed for fastening them.

It is difficult to explain the manner in which the fluids of the mouth act on the teeth. It is evidently not by an acidity of the secretions of the mouth, which would dissolve the earthy part instead of affecting the animal substance of the teeth. There is every reason for believing that the state of digestion influences the secretions of the mouth, and prepares them for acting on the teeth. The qualities of the food seem to have considerable effect. Some nations, as the Americans and the French, suffer from decay of the teeth even at an early age, while some other people scarcely ever lose their teeth by the process of decay. Mechanic trituration has no effect in producing decay. The inhabitants of Greenland, who chew the tough skin of the whale, have their teeth worn to the stumps, which are nevertheless perfectly sound.

On the Chemistry of the Digestive Organs. By Robert D. Thomson, *M.D.*

Having shortly reviewed the progress of knowledge on the chemical actions which take place in the stomach, the author proceeded to the further consideration of the subject under two heads:

I. Chemical state of the stomach: 1st, in health; and, 2ndly, in disease.

II. The chemical state of the mouth and œsophagus in health and disease.

I. 1st. He noticed Dr. Prout's discovery of free muriatic acid in the stomach during the excitement produced in it by digestion. The author mentioned the successful repetition by himself of an experiment of M. Blondelet, in which a substance similar to chyme had been prepared by digesting muscle in dilute muriatic acid at the temperature of the human body. He found, on repeating the experiment by digestion at a temperature of about 100° in the sand bath during ten hours, the fibre still retained a portion of its original colour. From these facts it may be inferred that free muriatic is an important auxiliary in the process of digestion.

2nd. The most common departure from the natural state of the stomach is a redundancy of acid, occasioned by the introduction of acid fruits and by the fermentation of vegetable matter. This form of dyspepsia is sufficiently well known under the common name of heart-burn. But the author showed that an alkaline state often exists which has hitherto been unobserved. He showed that pyrosis, or water brash, consists essentially of an alkaline secretion, instead of the natural acid secretion. A detail of the chemical analysis of the fluid emitted from the stomach in that disease showed that the alkali present was ammonia, and probably also free soda: 150 grs. were evaporated in a platinum crucible; when reduced to one third of its original bulk, the fluid con-

tinued to render reddened litmus paper blue, and emitted a somewhat caustic odour, not an ammoniacal one. When evaporated to dryness, the residue was white, and covered the bottom of the crucible in the form of a dried membrane. When heated, it became first red, then black, and gave out dark fumes and a strong smell of decomposed animal matter. When ignited 0·8 gr remained at the bottom of the crucible in the form of a white fused mass. Water being poured on the mass, the whole of it dissolved, with the exception of a few flocks. During the evaporation the evolution of ammonia was apparent. The nature of this complaint being thus quite obvious, the treatment consequent upon it is apparent. The author accordingly has found the employment of acid an effectual remedy. He recommends, however, when the disease is of considerable standing, to employ also anodynes, because the nerves being affected they require a direct application. He has found also that if the acid treatment is carried further than is necessary to re-establish the natural secretion, acid dyspepsia is apt to supervene. It is therefore proper to use in the first instance acid, and then bark or quinine. He has observed the disease to be excited in many cases by apples and porter; but has detected no general laws which seem to regulate the disease, as it occurs in persons of all ages, and of different constitutions and countries.

II. 1st. From an extended series of observations the author has deduced the conclusion that the fluid of the mouth in the natural state is either alkaline or neutral, generally the former, in conformity with the results of Dr. Donné of Paris. This gentleman has observed that when one of the poles of a delicate galvanometer is placed on the tongue and the other on the cheek, the needle deflects 15°, 20°, or 30°, in which case the mucus of the mouth will be the negative side and the skin the positive side; consequently the current proceeds from the mouth to the skin. Hence we have a kind of bile, which is formed by causing an acid and an alkali to communicate by means of an intermediate body. These experiments have been repeated and confirmed by Matteucci of Florence.

2nd. The author has confirmed the results of Donné relative to the secretions from the mucous and serous membranes being acid in inflammation. He has found this particularly in laryngitis, bronchitis, pneumonia, and in low typhoid fever, as well as in inflammatory diseases. He found the principal constituent of the membrane deposited in croup to be a substance approaching nearer to albumen in its properties than any other known matter, which would give support to the opinion that morbid products are deposited by the acid secreted on the surface of membranes. If this should turn out to be the case, the author suggested that an excellent method of retarding the formation of the membrane in the treatment of croup would be by the inhalation of ammonia.

The author, in conclusion, directed the attention of the Medical Section to the importance of these facts as features of diagnosis, and also as pointing out an improved method of practice by the local application of alkaline solutions, frequently repeated, to inflamed surfaces, as in gonorrhœa, sore throat, erysipelas, and all diseases where the natural secretion was alkaline and the abnormal one acid.

A short Exposition of the Functions of the Nervous Structure in the Human Frame. By Robert Reid, *M.D., M.R.I.A.*

The principal object of this communication was to enforce the method of studying the nervous system under three divisions: viz. the ganglionic, the spiral, and the cerebral systems. Dr. Reid pointed out what he conceived to be the principal function and province of each of these systems, and stated his opinion that all diseases should be arranged, and all remedies selected, according as the latter have their action directed to, and the former are found to affect one or other of these divisions of the nervous system in particular.

On Absorption. By Dr. Carson.

Dr. Carson, having shortly sketched the history of discoveries on the subject of absorption, and explained the nature of the questions relating to the functions of the red veins, lacteals, and lymphatics in this respect, proceeded to state his view of the operation of the red veins, with reference to the manner in which these veins communicate with the arteries. The author contended for an intermediate communication by means of cells, in all cases; that into these cells the extreme arteries poured their contents; that an extreme capillary artery had two communications, one with the particle which it had deposited for a fixed purpose, and another with the cell or channel common to it with the corresponding extreme vein, which was to receive the blood *not* to be deposited. The extreme vein in like manner had a double communication; one through the cell with the artery, another with the particle which had become useless in the system, and which was to be displaced by that deposited from the artery.

The change of colour which takes place at this point of union of the arterial and venous systems, the nature of the motion in the capillary vessels, the permanence of their tubular character, owing to the resistance of their parietes to external pressure, the nature of the changes taking place in the blood as it passes to the lungs, were then discussed. The lacteals and lymphatics being shortly noticed as employed in supplying nutriment to the system, by absorbing from the alimentary canal and from other internal surfaces, the author examined the analogous action of the imbibers to the lungs, stating reasons founded on the mechanism of respiration for the conclusion, based on experiments, that all the air which passes the bronchi enters the cavities of the veins and performs the circulation with the blood, yielding heat and ultimately nourishment to the frame.

Dr. Carson observes, "It would appear that the change or renovation of the frame is far more rapid than is generally supposed; that air expired in respiration is supplied by this renovation; and that the change must, in the course of any stated period, exceed the whole substance of the air expired in that period, as there are other channels through which other matters not so readily evaporable are discharged. It is contended

that the process of putrefaction proceeds as rapidly at least before death as it does after it, but that the products of it are carried off before they become offensive to the senses."

The last absorbent process mentioned is that by which the water in the ventricles of the brain is renewed. That this fluid is constantly in a state of renovation is certain from the fresh condition in animals that have been recently killed, and from the smell of substances of a fœtid nature being soon perceived in the water of the ventricles of the brain. There are no lymphatics in the brain. It would appear that the internal cavity of the ventricles, or the veins of the arachnoid coat, are supplied with imbibers, after the manner of the lungs; and that it is by these vessels, in connection with the exhalants, that the water of the ventricles is renewed. As there are no surfaces within the cranium from which liquids required for the repair of the system could be taken up, there would be, according to Dr. Carson's views of the uses of the lymphatic system, no employment for it; and he regards the total absence of these vessels from the brain as confirmatory of those views*.

On the Gyration of the Heart. By AUGUSTUS F. A. GREEVES, *Fellow of the Royal Colleges of Suregons of Edinburgh and London.*

The following are the propositions which the author endeavoured to establish:

1. Muscular fibres can act as levers without a *solid* fulcrum, if there be another set of fibres set at an angle and contracting simultaneously.

2. A hollow organ may be *dilated* by the *contraction* of such an arrangement of fibres, if in contracting they become more parallel to a plane passing longitudinally along the axis of the organ.

3. That there are two spiral, two longitudinal, and one diagonal set of fibres in the heart interlacing each other.

4. The ventricles gyrate incessantly to and fro upon their axis; *a*. In systole or involution, as the left hand pronates; *b*. In diastole or evolution, as the left hand supinates.

5. The double spiral curve of the two great arteries forms a compensating and regulating movement, causing,

6. First, a diminution of friction;

7. Second, steadiness and celerity of motion, on the principle of the tilt-hammer;

8. Third, an isochronous action, on the principle of the balance-wheel and spring;

9. Fourth, the progression of the *whole heart*.

10. That the function of the auricle is to maintain the equilibrium of the venous system.

11. The first sound is produced by the sudden tension and sudden

* See on this subject *Reports of the Association*, Vol. IV., Transactions of the Sections, p. 92, 93.

change of gyration, occasioning vibration of the ventricular walls. The second sound is from flapping of the sigmoid valves.

12. The impulse is partly caused by the progression, partly by atmospheric pressure, and chiefly by the left ventricle *first gyrating into the proper position to do so,* carrying the apex against the thorax with a force equal to the difference of strength between the right and left ventricles.

13. The pericardium forms a peripherad axis for the motions of the organ.

On the Functions of the Muscles and Nerves of the Eyeball. By John Walker, *Surgeon to the Eye Institution, Manchester.*

The action of the oblique muscles of the eyeball is explained by Mr. Walker as rotating the eye inwards, but by opposite rotatory movements; so that if the eye were rotated in one direction by the action of one of these muscles, it would be returned to its former position by the action of its antagonist; while, if both muscles were in action together, there would be no rotation at all, but a direct drawing of the eye inwards. An explanation of the reason for the complicated muscular apparatus of the eyeball is afforded in Mr. W.'s opinion by a reference to the arrangements of the nerves. The distribution of the third nerve to the superior internal and inferior rectus, and to the inferior oblique, points out the association of these muscles in all *corresponding motions of both eyes.* And the two other nerves (the 4th and 6th) with which the two remaining muscles, viz. the external rectus and superior oblique, are severally supplied, are required for the direction of one eye outwards, while the other is turned inwards, as is the case when even an object is viewed laterally.

Notice of a newly-discovered Peculiarity in the Structure of the Uterine Decidua, or Decidua Vera. By W. F. Montgomery, *M.D., Professor of Midwifery to the King and Queen's College of Physicians in Ireland.*

The author confines himself exclusively to a brief notice of a peculiarity in the structure of this product; which, as far as he is aware, has never been described, although perhaps one of its most important and interesting features.

About four years ago, while preparing the component parts of a human ovum in the third month for lecture, he observed that when the decidua vera was immersed in water, with its uterine surface uppermost, there appeared amongst the floating and shred-like processes which covered it certain small circular openings, which at first he took to be merely foramina in the membrane; but on attempting to pass the point of a fine glass rod through the opening, he found it to be a cul-de-sac, and being thus incited to ascertain how the matter really was, and examining carefully then, and having repeated the examination frequently

since, he has fully satisfied himself and others, who have examined the part with him, or to whom he has exhibited it in his lectures on embryology, both of its existence and peculiar character.

There are on the external or uterine surface of the decidua vera a great number of small cup-like elevations, which project from it. They are like little bags, the bottoms of which are attached to or embedded in the substance of the decidua; they then expand or belly out a little, and again grow smaller towards their outer or uterine end, which is in by far the greater number of them an open mouth, when separated from the uterus; how it may be while they are adherent, Dr. Montgomery does not decide. Their form is circular, or very nearly so, and in size they vary in diameter from $\frac{1}{12}$ to $\frac{1}{6}$ of an inch, and are elevated to about $\frac{1}{12}$ of an inch above the surface to which they adhere. In the way of comparison he would say that they were miniature representations of the suckers of the cuttle-fish. They are not confined to any one part of the decidua, and the author thinks they are usually most numerous and most distinct in those parts of it which are apart from the situation of the rudiments of the placenta, and at the period of gestation which precedes the formation of the latter (the placenta) as a distinct organ; hence the best time for examining them is up to the third month: in the advanced periods of gestation they are not to be found, at least Dr. Montgomery has not seen them then. The author observes further:

"I am ready to confess at once that I am not prepared to offer any very decided opinion as to the precise nature or use of these decidual cotyledons, for to that name their form as well as their situation appear strictly to entitle them; but, from having on more than one occasion observed within their cavity a milky or chylous fluid, I am disposed to consider them reservoirs for nutrient fluids, separated from the maternal blood, to be thence absorbed for the support and development of the ovum. This view appears strengthened when we consider, that at the early periods of gestation the ovum draws all its support by imbibition and by means of the connexion existing between the decidua and the villous processes on the surface of the chorion."

An Account of Human Twin Fœtuses, one of which was devoid of Brain, Heart, Lungs, and Liver; with Observations on the Nature and Cause of the Circulation in such Monsters. By John Houston, *M.D., M.R.I.A., &c., Dublin.*

Dr. Houston's observations were principally directed to the circulating system in the monster, though he described in full the various anomalous conditions of other organs in its body.

The placenta was double, with separate membranes and chords for each fœtus: the placenta of the imperfect infant was considerably smaller than that of the perfect one. The points of attachment of the two chords were several inches asunder.

The umbilical vein arising from the smaller placenta passed through the umbilicus, and opened into the vena cava abdominalis, the branches

of which all through the body were totally *devoid of valves*. The arterial system, commencing from the capillary terminations of the veins, ran together into a central vessel on the front of the lumbar vertebræ, making there a sort of aorta, like that in fishes, from which two umbilical arteries arose, and proceeded in the usual manner to the placenta. There was no communication between the venous and arterial systems such as that established in the natural condition by the foramen ovale and ductus arteriosus. By whatsoever system the blood entered the umbilicus of the fœtus, by the same it must have been distributed through all the textures of its body.

A round tumour existed in the substance of the chord outside the umbilicus, which during the growth of the fœtus had interfered with the freedom of the circulation: the umbilical vein was varicose between the tumour and the placenta, and the arteries were similarly affected from the opposite side of the same point, as far back as the aorta, as was readily ascertained by a comparison of the sizes of these vessels before and after they had passed the tumour.

Reviewing the facts of this case in connection with the published views of physiologists, Dr. Houston adopts the opinion that the blood in the placentæ and chords of both infants takes the same course, but that in circulating through their bodies the currents run in opposite directions; viz., that in both it arrives at the placenta by the veins, but that in the natural infant it is transferred from the umbilical vein to the aorta by the foramen ovale and ductus arteriosus, to be distributed thence in the usual manner; whilst in the monster, in which there is no such communication between the venous and arterial systems, it is conveyed all through the body by the veins, and is returned therefrom by the arteries.

As to the mode of circulation in the body of the monster, it is obvious, Dr. Houston observes, that the blood had but one course, and *that* the very reverse of what is usual. Having been conveyed thereto by the umbilical vein, it passed into the vena cava, and was distributed by the valveless branches of that vessel throughout all the textures of the body; it was there taken up by the capillaries constituting the roots of the aorta, and conducted thence out of the body again by the umbilical arteries.

On the Pathological Condition of the Bones in Chronic Rheumatism. By R. ADAMS, *Esq.*

The various changes taking place in the extremities of the bones which constitute the joints principally attacked by this disease, were minutely described, and illustrated by interesting specimens, casts, and drawings.

On the State of the new Circulating Channels in the case of double Popliteal Aneurism. By R. ADAMS, *Esq.*

Mr. Adams exhibited to the Section a preparation and drawings il-

lustrative of the changes which take place after the operation of tying the femoral artery, and pointed out some deductions of great importance to the surgeon which were to be drawn from a knowledge of the rapidity with which the anastomosing channels enlarge, with respect to the proper place of applying ligatures to wounded arteries.

Case of extensive Aneurism of the Arteria Innominata and Thoracic Aorta. By Sir DAVID J. H. DICKSON, *M.D., F.R.S.E., F.L.S.*

This paper was accompanied by a drawing of the diseased parts.

On the Question whether the Sense of Taste is dependent on Nerves from the Spheno-palatine Ganglion. By Mr. ALCOCK.

The statements in this paper were confirmative of the report by Dr. Hall and Mr. Broughton on the sensibility of the glosso-pharyngeal nerve.

On some particulars in the Anatomy of the Fifth Pair of Nerves. By Mr. ALCOCK.

Dr. HOWELL communicated a case in which a large portion of the ilium was eliminated from the body, the patient surviving more than twelve months: it was illustrated by drawings.

The Report of a Committee appointed in Dublin to pass opinion upon a Case exhibited by Mr. Snow Harris to the Section at the last Meeting of the Association was read by Dr. EVANSON.

The Committee are decidedly of opinion that this interesting case was not one of fracture of the neck of the thigh-bone, as had been supposed, but an instance of the disease known under the name of "Morbus Coxæ Senilis."

On a new Instrument for the removing of Ligatures at pleasure. By WILLIAM HETLING, *Surgeon, Infirmary, Bristol.*

In consequence of the pain, danger, and delay arising from the present mode of detaching the ligatures of arteries, Mr. Hetling invented the simple and easily constructed instrument, of which a description is appended, and verified its utility in cases which occurred in the Hospital at Bristol. He remarks that it is applicable not only to cases of amputation and aneurism, but to a ligature on any occasion, whether to an artery, vein, tumour, excrescence, polypi, hæmorrhoids, &c., and that in any unfortunate case of retained ligature, as commonly applied, it could easily be removed by a slight modification of the instrument.

Description of the Instrument.—It consists of a canula and two stilettes.

1st. A small silver flat canula, about one quarter of the diameter of a common female catheter, and like that instrument smoothly rounded at its extremity, through which a small hole is drilled, large enough to admit freely the silk thread of the ligature. It is light, and about two inches and a half long.

2nd. A flat and *blunt* silver stilette fitted to the tube of the canula, not quite long enough to reach the eye-hole through which the ligature passes. This stilette is for the temporary purpose of merely preventing the tube of the canula from becoming encrusted or clogged with blood, pus, lymph, &c., &c., till the period arrives for the removal of the ligature.

3rd. A steel *cutting* stilette ground to a sharp edge, flat and fitted to the whole tube of the canula, and extending beyond the hole through which the ligature has been drawn so as to admit of its dividing the noose of the ligature close to the knot, which when effected, enables both the ligature and instrument to come away with the utmost facility.

Mode of using it.—The artery is to be denuded quite in the usual manner. The ligature is then to be drawn through the eye of the canula, previously armed with the blunt silver stilette, and then passed round the artery in the usual way, tying the knot of the ligature close to the eye of the instrument. The ligature is then to be loosely twisted once round the canula, and both together left to lie obliquely out of the wound, as in the ordinary way. The instrument and ligature are then allowed to remain in this state until the period arrives for the removal of the ligature, which is easily accomplished by withdrawing the blunt stilette, and introducing in its stead the cutting one. The ligature and canula are then to be held together with the left hand, whilst the cutting stilette is pushed down the canula with the right, till encountering the noose stretched across its path, the edge cuts it off close to the knot, and the whole comes away without the least disturbance of the artery, by merely twisting the ligature between the finger and thumb (as well described by Sir Charles Bell for the removal of a common ligature), instead of the usual dangerous and painful practice of pulling and tugging it away with more or less violence.

Mr. Gordon exhibited a correct anatomical Model of the Human Body, carved in ivory, upon which he has been engaged for many years.

On the Sensibility of the Glosso-pharyngeal Nerve. By Dr. Marshall Hall, *and* S. D. Broughton, *Esq.*

The Committee of the Medical Section at the Cambridge Meeting of the Association appointed Dr. Marshall Hall and Mr. Broughton to investigate by experiments the disputed subject of the sensibilities of the cerebral nerves. A report was accordingly drawn up, and the results of the investigation were printed in the Transactions of the Association. To that report the authors have, at present, nothing further to add beyond a short notice respecting the sensibility of the *glosso-pharyngeal nerve.*

" It may be remembered that this nerve was the only one of the sensibility of which no demonstrable account could be rendered, no satisfactory experiment having been made upon it beyond what led to a mere negative result. It was freely exposed to view in an ass, irritated and divided, but no response occurred indicative of any apparent function. No muscular fibres were made to quiver by pinching or bruising the nerve; nor was any movement indicating pain observed; and when it was divided there was no apparent loss of any function. On the contrary, when the lingual branch of the fifth nerve was irritated, pain was expressed, and when it was divided, the surface of the tongue was deprived of tactile sensibility: also, when the ninth nerve was irritated, no sign of pain appeared, but the muscles of the tongue quivered; and when this nerve was divided, the voluntary motions of the tongue were destroyed, and the animal was unable to use its tongue.

" The evidences of the sense of *taste* were not investigated at all, being considered as satisfactorily demonstrated by Sir Charles Bell and M. Majendie to be referable to the lingual branch of the fifth nerve.

" Of the incorrectness of this hypothesis we never entertained a doubt until the appearance in this country of Professor Panizza's details of a course of experiments of ten years' standing upon the cerebral and spinal nerves*. Dr. Craigie's translation of the professor's account of his labours and results in the *Ed. Med. and Surgical Journal* is highly satisfactory, and leaves no doubt of the correctness of the experiments detailed.

" It has been gratifying to find that our results in reference to our paper read at the Edinburgh Meeting, stand generally confirmed by those of Panizza, with the important exception that the professor's experiments supply the deficiency of ours regarding the *glosso-pharyngeal nerve,* and explain the reason why we could not discover its sensibility by simply *irritating* and *dividing* it, without reference to the *gustatory* function of the tongue.

" The professor found that although the surfaceof the tongue became insensible to *mechanical injury* when the *fifth* nerves were divided, yet the sense of taste remained evidently recognised by the rejection and preference of certain substances. The *ninth* pair of nerves also being divided, the sense of taste continued to be exercised as usual, whilst the animal was thus deprived of the power of moving the tongue; and the *glosso-pharyngeal nerve* being divided, *no sense of taste was afterwards recognised.* 'The dog,' says Panizza, 'in which the *glosso-pharyngeal nerves* were divided, having recovered from the state of depression in which he was immediately after the operation, (the other nerves remaining entire,) *lapped water, and ate as freely as if he had suffered no injury, and afterwards mastication and deglutition were perfect; but he had no other guide than smell in the choice of his food, so that he swallowed with the same readiness the most disgusting and the most noxious, and the most agreeable and beneficial articles, provided either they did not smell, or their odour was artificially disguised, or*

* See *Ed. Med. and Surg. Journal* for January, 1836.

blended with another agreeable to the animal. The dog ate with equal avidity fresh animal food, or that rendered bitter by the same substance. A morsel of flesh pounded minutely in coloquintiva solution he eat, and even licked the rest of the fluid in the vessel.'—'At the same time (continues Panizza) I experimented upon another dog, in which I had cut off the *two lingual nerves* (branches of the fifth pair), and after swallowing morsels of flesh with avidity, *he swallowed an embittered portion also*; but it was scarcely in the gullet when he was attacked with vomiting, and obliged to disgorge it: when it was presented to the dog in which the glosso-pharyngeal nerve was divided on each side, he *ate it immediately without any sign of disgust*.'

"With respect to the anatomical distribution of the glosso-pharyngeal nerve, the professor says, 'In man, the dog, &c., it is wholly distributed to the *mucous membrane* of the tongue, and the other parts which have the sense of taste in common with the tongue, and towards the base of the tongue, where the nerves are most numerous and the sense of taste is most acute.'

"Not doubting the accuracy of these observations, we were nevertheless desirous of communicating to the Section at the present Meeting our repetition of Panizza's experiment on the glosso-pharyngeal nerve and its results, which are quite in accordance with those of the Italian professor, and thus render our original task more complete. The experiment was conducted with great care and caution in the dissecting rooms of our talented and skilful friend Mr. Lane of Grosvenor Place, to whose hands, as an independent party, was consigned the necessary operation.

"Previously to the experiment, accurate dissections and surveys were made of the parts concerned in the intricate distribution of the nerves about the throat. A small dog of the terrier breed was preferred, with a long and lanky neck, one central incision sufficing for both nerves: the *glosso-pharyngeal nerve* was divided on each side, and a piece cut out of about $\frac{3}{4}$ of an inch long. No attempt was on this occasion made to prove the sensibility of this nerve to pain, as this cannot be so well effected in a dog as in a horse or an ass, the latter having (in our original experiments) been allowed to stand up unconstrained after the exposure of the nerve, so that any feeling experienced on irritating the nerve might be freely expressed; the struggles of an animal held down forcibly being likely to embarrass the observations made.

"As soon as the dog had recovered from the necessary exhaustion of its situation, a piece of meat rubbed over with aloes was offered to it, *which it ate, and it lapped water as usual*. The next evening we re-assembled, and offered the dog fresh meat, which it eagerly ate. The next morsel offered was rubbed over with a strong solution of the extract of colocynth, which he snapped up, but instantly ejected from the mouth, took it up again, and swallowed it with a little hesitation. Although the odour of the extract is very slight, we resolved on the next occasion to use the coloquintida powder, which is quite free from odour, and also the quinine. A second similarly embittered morsel was however offered the dog, which he ate unhesitatingly; a third morsel was smelt

at and rejected, and so indeed was a piece of fresh meat untainted, his appetite being apparently satisfied or yielding to instinctive caution.

"In a few days we again assembled and introduced another terrier dog, not experimented upon. Some pieces of fresh meat were cast before each dog on this occasion, and they both indicated voracious appetite. The next morsels were successively rubbed over with quinine, extract of colocynth, and coloquintida powder: the dog not operated upon bolted the morsel with the *quinine*, but rejected the others in succession; but the dog on which the experiment was performed ate all the medicated morsels without reserve, exhibiting at several repetitions some degree of caution and distrust, more than might perhaps have been evinced in eating the sound and fresh meats.

"We then stirred up a considerable quantity of the extract of colocynth in a bowl of milk, which the dog not operated on began to lap, but instantly desisted with an expression of disgust: it was next placed before the dog operated on, and he *instantly and voraciously lapped it all up*.

"Such has been our experiment on the sense of taste; and on comparing the phænomena mentioned by Panizza with those just detailed, a strict coincidence is observable. After the division of the nerve *no diminution in the power of protruding the tongue occurred, and the dog could still lap, masticate, and swallow,* and although in possession of the other nerves of the tongue entire, when the glosso-pharyngeal nerve was divided on each side, *the recognition of the sense of taste was obviously lost,* for substances of disgustingly pungent and bitter flavour, which dogs will not eat if tasted, were devoured indiscriminately with solid meat and milk.

"We therefore beg to submit to the deliberate consideration of the Section, whether there be not grounds sufficient to warrant the presumption of that hypothesis being fallacious, which ascribes the specific sense of taste to the lingual branches of the fifth pair of nerves, and the power of deglutition to the glosso-pharyngeal nerves? We feel that we are fully warranted in acknowledging the conviction to which Panizza's experiments tend, as to the separate functions and sensibilities of the nerves of the tongue, corroborated as they are by our own observations.

"The sense of *taste* has never long together enjoyed any fixed locality amongst the lingual nerves, and each nerve in its turn has been deemed the gustatory nerve, whilst all three pairs have also been supposed to be concerned in the propagation of flavours to the sensorium. Latterly, indeed, the experiments of Sir Charles Bell and M. Majendie have induced a train of reasoning which terminated the question in favour of the fifth pair of nerves being alone concerned in the sense of taste, and anatomy is referred to in support of this notion; nevertheless, Professor Panizza was led to doubt the hypothesis on anatomical grounds, and his researches confirmed his doubts, he having found this nerve ramified upon the mucous membrane of the tongue only. Without, however, entering upon the controversial details of the case, it may be as well to state, that Mr. Owen, the intelligent comparative anatomist of

the College of Surgeons' museum, has observed (before he was aware of Panizza's experiments) in Dr. Todd's *Cyclopædia*, in the article upon *Birds*, that *he never could discover any nerve corresponding with that which in mammalia is called the* GUSTATORY NERVE *in the tongues of birds, and that the* GLOSSO-PHARYNGEAL *nerve is freely distributed amongst the soft papillæ* of the tongue, and lost where the tip in some birds is covered with a horny cuticle. *The glosso-pharyngeal nerve* moreover, is not found in fishes, which have no papillæ for the propagation of taste, but the organ of smell powerfully developed, and whilst the fifth and the ninth branches are liberally distributed. In the assumed function of the *glosso-pharyngeal nerve* we find a close analogy to the *optic nerve and the retina;* the latter possess no sense of common feeling or tact, but they are the media of a specific sense exclusively of all other sensations, and have no influence upon motion; and such appears to be the character of the glosso-pharyngeal nerve.

Anatomy, both human and comparative, appears to corroborate the notion of the glosso-pharyngeal nerve being that which ought properly to be termed in future "GUSTATORY"; at the same time we may ascribe "*tactile sensibility*" to the lingual branches of the fifth, and *deglutition* and *mastication* to those of the *ninth* pair of nerves exclusively.

MECHANICAL SCIENCE.

On the Theory of British Naval Architecture. By HENRY CHATFIELD, *Naval Architect.*

The author, after noticing the general disadvantage under which this country has laboured from not having applied the principles of science to ship-building, and the insufficiency of the experiments hitherto made on the construction and qualities of ships, proposes as a means of reducing the theory of British naval architecture to correct principles, to make it a part of an *official system* in the department of naval architecture to register, in a very systematic manner, the minutest calculations by which it is attempted to predict a ship's qualities at sea; and to make an equally systematic arrangement of faithfully observed results to which the calculated predictions refer. Comparisons might thus be instituted which would tend gradually to the establishment of correct principles in cases where pure mathematics are insufficient.

Mr. Chatfield contrasts with the precise information which would thus be gathered, the vague notions, rather than data, which have been collected in the official reports of what are called "ships' sailing qualifications"; replies to objections which have been urged against the attempt at numerical precision in recording observations of this nature made at sea, by showing that the nature of the problems to be solved requires accurate data expressed numerically; admits that to prosecute the subject in an adequate manner and with a reasonable chance of suc-

cess, would be a laborious task; but shows by reference to the excellent condition of the science of *navigation*, that by great attention in collecting and classifying facts, the practice of *naval architecture* might be raised to a corresponding degree of perfection.

On certain points in the Theory of Naval Architecture. By Mr. HENWOOD.

On the Tides. By the Rev. W. WHEWELL, *F.R.S.*

In this communication Mr. Whewell explained the state of knowledge concerning the tide, to which recent investigations had conducted; pointed out the importance of a continuous tide register in furnishing data for the improvement of this important branch of science; and exhibited a model of a tide machine now in the course of erection under Mr. Bunt's direction.

Dr. LARDNER explained his views of the most advantageous modes of forming a steam communication with the East Indies and North America*.

On the Application of our Knowledge of the Phænomena of Waves to the Improvement of the Navigation of Shallow Rivers. By J. S. RUSSELL.

JOHN ROBISON, Esq., suggested, and illustrated by a diagram, a method of measuring the interval and the velocity of waves at sea, by two ships kept parallel to and equidistant from each other, and counting the crests of waves between them.

On certain points connected with the Theory of Locomotion. By Professor MOSELEY.

On the Performance of Steam-Engines in Cornwall. By JOHN S. ENYS.

The object of the paper was to point out that within the last few months the work done (or the duty) per imperial bushel of Welsh coal, weighing on an average ninety-four lbs. had been more than doubled as compared with similar engines, by two engines employed in stamping ore, erected by Mr. James Sims; and that, making allowance for the difference of lifting stamp heads (or actual weight) with an uniform resistance, and lifting a weight of water, calculated from the size of the pumps, with a variable resistance exactly suited to a high-pressure expansion engine, a duty of fifty million lbs. raised one foot high per

* See on this subject the *Edinburgh Review*. 1837.

bushel of coal might be considered equivalent to eighty millions lifted in a pumping engine. Taking the quantity of water lately found, chiefly through the exertions of John Taylor, Esq., to have been evaporated per bushel, it was shown that the cubic feet of steam which could be formed by the consumption of the known quantity of coal per month, would readily supply the quantity of steam required in the cylinder per month, and be capable of producing at each stroke a mean pressure in the cylinder equal to the sum of the work done in the pump (that is the calculated weight of the water), the friction of the pit work, and the friction of the engine itself.

The calculations most relied on referred to a large engine, the pressure of whose steam had been ascertained by an excellent indicator from the North of England.

Joseph T. Price of Neath Abbey exhibited the model of a pair of paddle-wheels which he had fixed on the Lord Beresford steamer at Southampton, in substitution of a pair of ordinary wheels.

It has an eccentric wheel fixed to the side of the vessel, in which a band is placed, having rods leading to cranks on each paddle iron; these have each an axis, and hence as the engine moves the shaft and its paddle arms, the eccentric with its rods and cranks produces a motion which ensures the nearly vertical insertion of the paddle board or irons into the water, and when lifting turn it in like manner nearly vertically, hereby avoiding the pernicious effects of ordinary paddles, when from any cause they happen to be wading in water beyond the limit allotted them in smooth water, with the ship in exact trim.

The effect J. T. Price described to be *great relief to the engine*, in so much that about two thirds the coal would produce an effect in the speed of the vessel, otherwise under equal circumstances, equivalent to her former speed, by cutting off part of the steam equal to the reduced resistance of the paddles in the water. The objection to these paddles J. T. Price fully admitted to lie in the additional liability to require repair, and the consequent need of attention; but he resolved this into a simple question of expense, and assuming that it might cost 100*l* per annum more to maintain these than the ordinary paddles, which if all needful spare articles were constantly kept ready, he contended would suffice for a pair of forty-horse engines (say eighty-horse power), there appeared to him a *clear advantage* in their favour in the œconomy of fuel or in accelerating the voyages to be performed by the vessel employing them.

Mr. Gower described the nature and construction of the boiler used in the steam-packet Vesta, the bottom of which is covered to a small depth with mercury, for the purpose of equalizing the distribution of heat, and regulating the evolution of steam.

Mr. Braham exhibited an improvement on Pope's fluid compass, by which he hoped to prevent wear of the pivot and cap, unsteady action, change of direction in the card, and obliteration of the points stamped on it.

Dr. Daubeny exhibited an instrument intended for drawing up water from great depths.

Mr. Hawkins exhibited and described an improvement of Napier's Rods, by J. N. Cossham, Esq. of Bristol.

The invention consists in cutting each of Napier's rods into ten cubes, and in stringing the cubes together by means of pins passing through two perforations in each cube, the perforations being made at right angles to each other, and parallel to the planes and boundaries of the figured faces, and passing by without crossing the middle of the cube. By this arrangement the cubes may be readily placed in such positions that the product may be obtained by addition only, without the necessity of previously transcribing the number from the cubes, thus avoiding a great liability to error, and effecting a saving of time in the calculation.

Mr. John Murray forwarded for exhibition a model of a life boat upon a new construction, accompanied by descriptive notices, and a work printed upon paper made from the New Zealand flax, (*Phormium tenax*.)

STATISTICS.

Researches relative to the Price of Grain, and its Influence on the French Population. By Baron Dupin, *President of the Institute of France.*

In this communication the Baron observed that the small annual variation in births, deaths, and marriages, even for years of great difference of price, induced him to search for a *function* of these three social elements, which would both render the variations more perceptible, and correcting one by the other, would remove the perturbations arising from accidental causes. This function is the mean between the numbers of births divided by the number of deaths, and the number of marriages divided by the number of deaths. It is sufficiently obvious that this function is independent of the amount of population, and the Baron considered that the magnitude is a very fair test of social prosperity. He proposed to name it the function of vitality. In the years of extreme scarcity, the function of vitality averaged 0·5937 ; in the years of high prices it averaged 0·6092 ; in the years of intermediate prices it averaged 0·6168. He then observed that according to Dr. Cleland's paper, read on the preceding day, the function of vitality in Glasgow was about 0·7000, a clear proof that social happiness was greater in England than in France. He trusted that this function would be calculated for the principal continental nations, and for different epochs, in order to compare their social prosperity by a precise and identical standard. As one

valuable result, he showed that this function was far less in England during seasons of commercial depression than of agricultural distress.

[This extract is taken from Dr. Cleland's Statistical Documents relating to Glasgow.]

Mr. Porter presented the following statement of data drawn up by himself, for the determining of this function in England:

	Price of Wheat.	Baptisms.	Burials.	Marriages.
	Shillings.			
1801	115·11	237	204	67
1802	67·9	273	199	90
1803	57·1	294	203	94
1810	103·2	298	208	84
1812	122·8	301	190	82
1815	63·8	344	197	99
1822	43·3	372	220	98

Baron Dupin explained two maps of Britain, shaded so as to represent, 1, the density of population; 2, the degree of criminality. He presented tables showing the relative amount of male and female offenders, and the relation of criminality to education.

Report on the State of Education in the Borough of Liverpool, in 1835—1836 *.

This report was communicated to the Section by the Manchester Statistical Society, having been drawn up by a Committee of that Society, under whose direction the inquiry was conducted. The report has been published by the Society since the meeting of the Association.

In collecting the materials for this report, each school of every class had been visited, and the facts thus obtained by personal inspection and the testimony of the teachers were classified in numerous tables. The result proved that the returns made to Government in 1833 were exceedingly defective; in the parish of Liverpool alone the deficiency amounting to no less than 13,500 scholars, the returns from the outtownships being also grossly inaccurate.

The whole number of children attending the schools in the borough of Liverpool was found by the Committee to be 33,183, *viz.*

17,815, or $7\frac{3}{4}$ per cent. of the population, attending day or evening schools *only*.

11,649, or 5 per cent. of the population, attending *both* day and Sunday schools.

3,719, or $1\frac{2}{3}$ per cent. of the population, attending Sunday schools *only*.

33,183, or $14\frac{2}{5}$ per cent. of the population.

* See in relation to this subject, vol. iv. p. 119.

Of this number about 6000 were under 5, or above 15 years of age. Thus 27,200 children between the ages of 5 and 15 were found to be attending school, whereas it is estimated that there are in the borough 57,500 children of corresponding age (or one fourth of the total population of 230,000); and it consequently appears that 30,300 children between 5 and 15 years old (or more than half of the whole number of children of that age), were not attending any schools whatever, at the time of the inquiry.

The Report minutely examines the quality and extent of the instruction professed to be given in each class of schools, with the exception of those where the children of the wealthier ranks are instructed. The appendix contains a detailed account of the charity schools, which are numerous. Most of them are connected with the Sunday schools or congregations of particular sects, the members of which contribute to defray the expenses of their schools. The Sunday schools themselves form a very unimportant item in the sum total of the existing means of education.

The Committee state in the following general terms the conclusions to which their inquiries have led them.

First.—Of the whole number of children in the borough of an age to be instructed more than one-half are receiving no education in schools, either really or nominally.

Secondly.—Of those who do attend school, more than one-third are the children attending dame and common day schools, some of whom acquire nothing by their attendance at school to which the term education can reasonably be applied, and the remainder, with few exceptions, receive an education of the very lowest description.

Fifthly.—The remaining schools, for the education of the children of the lower classes, consist chiefly of charity schools, some of which have infant, and most of which have Sunday schools attached to them; they receive, within their walls, about forty-five per cent. of the whole number of children attending school in the borough, and are supported, in great part, by the funds of private individuals. The education given in these schools is of a more effective kind. The school rooms are more airy and spacious; and the teachers are often of a higher and better educated class, and have stronger motives to the zealous discharge of their duties.

Further.—The result of the Committee's inquiries may be expressed in the following condensed form:

12,000 Children of all ages receiving, entirely at the cost of the parent, an education of a very low order.

13,000 Children of all ages receiving, partly at the expense of the parents, partly from private benevolence, an education more or less effective, but in all cases of some real value to the child.

3,700 Children of all ages receiving some little instruction in Sunday schools, but no regular education.

4,000 Children of the upper and middle classes, educated in superior private schools.

32,700 Children of all ages receiving instruction, of whom 26,700 are between 5 and 15 years old; and there are not less than 30,000 children between the ages of 5 and 15 receiving no education in schools either really or nominally.

GENERAL SUMMARY OF SCHOOLS AND SCHOLARS IN THE BOROUGH OF LIVERPOOL 1835—36.

DESCRIPTION OF SCHOOLS.	PARISH OF LIVERPOOL.		SUBURBS.		BOROUGH OF LIVERPOOL, POPULATION ESTIMATED AT 230,000.									
					AGE.			SEX.		TOTAL.		PER CENTAGE.		
	Schools.	Scholars.	Schools.	Scholars.	Under 5.	Between 5 and 15.	Above 15.	Male.	Female.	Schools.	Scholars.	Of the total Population estimated at 230,000	Of the total number of Scholars.	Of the total number of Sunday Scholars.
Sunday Schools.														
Church of England	18	4521	9	1797	82	6208	28	3459	2859	27	6318	2·75	19·04	41·11
Roman Catholic	1	370	1	330	...	700	...	430	270	2	700	·30	2·11	4·56
Dissenters	35	6671	11	1679	299	6974	1077	4229	4121	46	8350	3·63	25·16	54·33
Total	54	11562	21	3806	381	13882	1105	8118	7250	75	15368	6·68	46·31	100·00
					2·48 p c	90·33 p c	7·19 p c	52·82 p c	47·18 p c					Of the total number of Day Scholars.
Returned also as Day or Evening Scholars	...	8403	...	3246							11649	5·06	35·10	
Receiving Sunday School tuition *only*	...	3159	...	560							3719	1·62	11·21	
Day Schools.														
Dame Schools	202	4471	42	769	1928	3312	...	2168	3072	244	5240	2·28	15·79	18·12
Common Boys' and Girls' Schools	156	5107	38	989	573	5448	75	3421	2675	194	6096	2·65	18·37	21·08
Superior Private and Boarding Schools	86	2609	57	1471	161	3637	282	2111	1969	143	4080	1·77	12·30	14·11
Infant Schools: Supported solely by the Scholars	444	12187	137	3229	2662	12397	357	7700	7716	581	15416	6·70	46·46	53·31
Infant Schools assisted by the Public	10	1463	7	742	1318	887	...	1118	1087	17	2205	·96	6·64	7·63
Other Charity Schools, Schools attached to Public Institutions, &c. (*Vide List.*)	35	8578	15	2717	86	11045	164	6582	4713	50	11295	4·91	34·04	39·06
Total	489	22228	159	6688	4066	24329	521	15400	13516	648	28916	12·57	87·14	100·00
					14·06 p c	84·14 p c	1·80 p c	53·26 p c	46·74 p c					
Evening Schools. Supported by the Scholars, exclusive of the classes at the Mechanics' Institution, and at the Literary, Scientific and Commercial Institution ...	39	507	4	41	...	237	311	425	123	43	548	·24	1·65	
						43·25 p c	56·75 p c	77·55 p c	22·45 p c					
Total Number of Schools and Scholars	582	25894	184	7289						766	33183	14·43	100·00	
Evening School attached to a Sunday School	...	...	1	40	...	...	...	...	...	1	40			
Average attendance at Sunday Schools	...	...	...	...	...	...	...	...	...	...	11715			

COMPARATIVE STATEMENT OF THE NUMBERS RECEIVING INSTRUCTION.	IN THE BOROUGHS OF MANCHESTER & SALFORD, 1834-5.			IN THE BOROUGH OF LIVERPOOL. 1835-36.		
	Scholars.	*Per Centage.* Of the total Population estimated at 255,000.	*Per Centage.* Of the total number of Scholars.	Scholars.	*Per Centage.* Of the total Population estimated at 230,000.	*Per Centage.* Of the total number of Scholars.
Attending Day or Evening Schools *only*	13239	5·20	23·56	17815	7·75	53·69
Attending both Day or Evening and Sunday Schools	13121	5·26	23·89	11649	5·06	35·10
	26660	10·46	47·45	29464	12·81	88·79
Attending Sunday Schools *only*........	29529	11·58	52·55	3719	1·62	11·21
	56189	22·04	100·00	33183	14·43	100·00
Number of Scholars estimated to be under five or above fifteen years of age	12000			6000		
Children between five and fifteen years of age attending Schools	44189			27183		
Estimate of the total number of Children in the boroughs between five and fifteen years old	63750			57500		
Estimated number of Children between five and fifteen years old, not receiving any instruction at Schools	19561			30317		
Proportion which the number of Children between five and fifteen, *receiving no instruction at School*, bears to the *total* number of Children between the same ages	30 7 p c			52·7 p c		

On the Statistics of Popular Education in Bristol. *By* C. B. Fripp, *Esq.*

After some general remarks on the importance of statistical inquiries into the state of education in the different towns of the kingdom, with the view of comparing their condition in this respect, and of illustrating the deficiencies which exist in our present means of instruction, the author stated that, as the best means in his power of obtaining the requisite information in Bristol, he had addressed eighty circulars to the clergy and other ministers of religion, soliciting their replies to various queries annexed in a schedule. With very few and unimportant exceptions, these schedules were returned duly filled up, and from these returns various tables were compiled, exhibiting the details in such a manner as to admit of their comparison with those published by the Manchester Statistical Society. Due care was taken to avoid errors from duplicate returns where the children attended more than one school, and although some errors of omission may have occurred, the author considers the returns as indicating very nearly the actual extent of popular education in Bristol. It is to be observed however that the returns are confined to *public* schools, whether day, infant, or Sunday, and do not include the children attending private schools or dame schools. The instruction given in the latter class of schools is so very limited and elementary, that it hardly deserves the name, and as most of the children attending them also attend Sunday schools and are returned under this head, the omission is of little practical importance.

The returns relative to the Roman Catholic schools were not received in time to include them in the tabular statements, and are therefore to be added to the numbers exhibited in the following abstract. In these schools there are boys, 123; girls, 92; total 215; being an increase of 58 boys and 33 girls since 1821. The number of Roman Catholics in Bristol at that period is estimated at 3000, at the present time it is above 5000. The instruction is wholly gratuitous, and embraces book-keeping and some of the practical mathematics.

The population of Bristol and its suburbs (now incorporated in the new borough) according to the census of 1831 was 104,378.

Which number at the usual rate of increase ($1\frac{1}{2}$ per cent. per ann.) would now amount to 112,438.

The total number of *schools* of which returns have been obtained is 128, of which there are,

		Scholars.		Scholars.	
Day schools	51	with 4,130,	of whom	1526	attend Sunday schools also.
Infant	9	.. 1,124,	......	119	ditto.
Sunday ..	68	.. 11,108.		——	
	128	16,362			

Deduct duplicates.. 1,645, leaves scholars 14,717.

In both day and infant schools the number of boys is greater than that of girls; in the *Sunday* schools the proportions are reversed.

Of the 14,717 *scholars*:

	Scholars.	Per cent. of Pop.
Attend day or infant schools *only*	3609	...... 3·20
.. day or infant *and* Sunday schools	1645	...... 1·46
.. Sunday schools *only*	9463	...... 8·42
	14,717	13·08

Thus it would appear that the number of children receiving instruction *every day* is only 35·70 per cent. of the total number under instruction, and 64·30 per cent. of that number receive only *Sunday* instruction.

On comparing the number of children under instruction in Bristol and some other places of which we have accurate returns, the results are as follow:

Receiving Instruction in	Per cent. of Population.			
	Bury.	Manchester and Salford.	Liverpool.	Bristol.
Day and infant schools	13·1	10·46	12·81	4·66
Sunday Schools *only*	15·5	11·58	1·62	8·42
Total	28·6	22·04	14·43	13·08
or	1 to 3·5	1 to 4·6	1 to 6·9	1 to 7·6
		persons.		

It is evident from this comparison that after making the most ample allowance for accidental omissions and for the *private* schools not included in the Bristol returns, the state of education in this city is far from satisfactory, looking merely to the *number* of the children receiving instruction.

Classified according to *age*, the returns obtained exhibit

	Scholars.	Per cent. of Pop.	Per cent. of Est. No. of Scholars.
Under 5 years	1290	1·14	8·77
Between 5 and 15 years. . . .	12,630	11·23	85·82
Above 15, or not specified. .	797	0·71	5·41
	14,717	13·08	100·00

It has been usual to employ an analysis of this sort for the purpose of showing the proportion of the instructed and uninstructed in the youthful population, but the author pointed out the fallacy of assuming that because the numbers at any one time under instruction between the ages of five and fifteen fall greatly short of the proportion between the same ages in the population at large (taken by the Manchester Statistical Society at twenty-five per cent.), the whole of those thus unaccounted for must be entirely without instruction. It is evident that a great number of children may receive instruction for short intervals and from time to time, though not being at school when the returns are made, they would appear among those unaccounted for, and considered uninstructed. The only mode to obtain correct results on this point, would be to ascertain the number under instruction, according to their several ages, *from year to year*, between five and fifteen, and then to compare these numbers with those of the same ages in the population at large at the same time. From the neglect of this distinction, some very startling results, which can hardly be received as true, have been laid before the public on high statistical authority.

Maintenance of Schools. Of the *day* schools there are twelve wholly, and ten others partially supported by endowment; twenty-one by public subscription and payments from the scholars; four by public subscription only; two by the sole payments of the scholars; and two out of the poor rates.

The nine *infant* schools, with one exception, where there is a partial endowment, are maintained by subscription, and payments from the children.

Of the sixty-eight *Sunday* schools, sixty-five are wholly supported by private and public subscriptions; one by the poor rate; and two by endowment, subscription, and payment jointly.

The rate of payment by the scholars varies from a halfpenny (in one school) to threepence per week (in two schools), but in the majority of cases it is either a penny or twopence per week.

Instruction. In sixty-six out of the sixty-eight Sunday schools, the instruction is confined to reading, religion, and morals; in the other two (under the management of the Society of Friends) writing is also taught.

Writing and arithmetic are taught in two of the *infant* schools; in the other seven, only reading and the elements of religion.

In forty-three out of the fifty-one *daily* schools, the pupils learn to write; in thirty-seven to use figures; in fifteen they have some instruction in geography and history; and in two, a slight admixture of mathematics. Drawing is not taught in any of the schools.

Religious Distinction. In connection with the Established Church there are

Day Schools	26
Infant	5
Sunday	18
Total	49

which (after deducting duplicate returns) contain 4375 scholars, with 214 teachers. The average attendance is about eighty-five per cent. of the number on the books.

In connection with the Wesleyan Methodists there are

Day Schools	4
Sunday	19
Total	23

containing 3839 children, with 626 teachers. The average attendance is about seventy per cent. of the number on the books.

In connection with other religious bodies distinct or dissenting from the Established Church, there are

Day Schools	11
Infant	3
Sunday	25
Total	39

containing 5026 scholars, with 591 teachers. The average attendance is about eighty-five per cent. of the numbers on the books.

Unconnected with any particular denomination there are

Day Schools	10
Infant	1
Sunday	6
Total	17

containing 1477 scholars, with 74 teachers. The average attendance is about eighty-five per cent. of the numbers on the books.

Almost all the *endowed* schools are connected with the Established Church. In many schools (particularly Sunday schools) which are supported at the charge of particular denominations, scholars of all creeds are received, and in few comparatively is a strictly exclusive character maintained.

Dates of Establishment. On this point the returns were considerably defective, but on the whole, it appears that of the total number of schools now existing in Bristol, nearly *one-half* have been established since 1820, and nearly *one-fourth* since 1830.

Mr. F. concluded his paper with some remarks on the influence of education in its present state as compared with what it should be on a wider and more efficient basis. He referred in illustration to the course of primary instruction established in the Canton of Zurich, as one of the most complete and rational schemes of cultivating the mind of a people that have yet been proposed. In an appendix, the author gave an account of the foundation and nature of instruction pursued in the endowed schools of Bristol.

Extracts from Statistical Documents relating to Glasgow, drawn up by Dr. Cleland*, *President of the Glasgow and Clydesdale Statistical Society.*

Population of Glasgow.

Year.	Souls.	Year.	Souls.	Year.	Souls.
1560	4500	1740	17034	1791	66578
1610	7644	1755	23546	1801	77385
1660	14678	1763	28300	1811	100749
1688	11948	1780	42832	1821	147043
1708	12766	1785	45889	1831	202426
1712	13832				

The suburbs were included, for the first time in 1780. It will be seen that the population fell off immediately after the restoration of Charles II., in 1660, and that it required more than half a century to make up what it had lost.

* In connexion with these documents see vol. iii. p. 688.

Education.—In 1816, exclusive of the University, and 13 institutions in the city wherein youth were educated, there were 144 schools. Including the public institutions, 16,799 scholars, of whom 6,516 were taught gratis in charity or free schools. Several of these however attended more than one school. In 1820 there were 106 Sunday schools, 158 teachers, 4,668 scholars, viz. boys 2,235, girls 2,433, besides 3 adult schools, where there were 3 teachers, and 25 male and 54 female scholars. Since 1820 the number of Sunday schools has greatly increased.

River Clyde.—In 1653 the merchants of Glasgow had their shipping harbour on the Ayrshire coast. This port being distant, and land-carriage expensive, the magistrates in 1658 negotiated with the magistrates of Dumbarton for the purchase of ground for a harbour; after some discussion, the negotiation broke up, the authorities of Dumbarton considering that "the great influx of mariners would *raise the price of provisions to the inhabitants*." In 1662 the corporation of Glasgow purchased ground and laid out the town of Port-Glasgow for their shipping harbour, and in 1668 they built a small quay at the Broomielaw; Mr. John Golburn, civil engineer, inspected the river, and on the 30th November 1768 reported that it was in a state of nature, and that as far down as Kilpatrick there were only two feet of water. In 1775 Mr. Golburn had so far improved the navigation that vessels drawing six feet water could come up to Glasgow at the height of a spring tide. Less than 50 years ago gabbarts, and these only about 30 or 40 tons burthen, could come up to the city; and Dr. Cleland recollects when for weeks together not a vessel of any description was to be found at the port. The increase of trade consequent on the improvements of the river almost exceeds belief. By the year 1831 vessels drawing 13 feet 6 inches water came up to the harbour; and now large vessels, many of them upwards of 300 tons burthen, are to be found three deep along nearly the whole length of the harbour. During the year 1834, about 27,000 vessels passed Renfrew ferry, and at some periods in that year between 20 and 30 in an hour. A few years ago the harbour was only 730 feet long, and all on the north side of the river. It is now 1,260 feet long on the south, and 3,340 on the north. There are four steam dredging machines and two diving bells employed in deepening the harbour and river.

Amount of the Revenue, Expenditure, and Debt of the River.

Date.	Revenue.			Expenditure.			Debt.		
	£	s.	d.	£	s.	d.	£	s.	d.
1770	147	0	10	2,680	4	11	2,533	4	1
1780	1,515	8	4	1,509	0	$0\frac{1}{4}$	21,305	3	1
1790	2,239	0	4	1,884	17	$1\frac{1}{2}$	17,864	18	$5\frac{1}{2}$
1800	3,319	16	1	1,904	8	8	11,001	7	5
1810	6,676	7	6	35,210	9	7	28,706	16	6
1820	6,328	18	10	7,076	12	2	49,736	18	10
1830	20,296	18	6	24,821	8	8	113,947	2	8
1835	31,910	19	3	29,609	13	11	124,003	13	9
1836	35,577	16	0	..	..	..	129,882	10	5

Another proof of the increase of trade from the improvements on the river will be found in the duties paid at the Custom-house, as exhibited in the following table :

Amount of Customs Duties collected at Glasgow in years ending 5th January.

Years.	Duties.			Years.	Duties.			Years.	Duties.			Years.	Duties.		
	£	s.	d.		£	s.	d.		£	s.	d.		£	s.	d.
1812	3124	2	$4\frac{1}{4}$	1819	8384	3	4	1825	41,154	6	7	1831	72,053	17	4
1813	7511	6	$5\frac{1}{2}$	1820	11,000	6	9	1826	78,958	13	$8\frac{1}{2}$	1832	68,741	5	9
1814	7419	12	$8\frac{1}{4}$	1821	11,428	19	0	1827	71,922	8	$0\frac{3}{4}$	1833	97,041	11	11
1815	8300	4	$3\frac{3}{4}$	1822	16,147	17	7	1828	74,255	0	$1\frac{1}{4}$	1834	166,913	3	3
1816	8422	9	$2\frac{3}{4}$	1823	22,728	17	$2\frac{1}{2}$	1829	70,964	8	4	1835	270,667	8	9
1817	8290	18	1	1824	29,926	15	0	1830	59,013	17	3	1836	314,701	10	8
1818	6802	1	3												

Steam Vessels which sailed from Glasgow in 1831 and 1835.

ABSTRACT.

	1831.		1835.	
	Vessels.	Tonnage.	Vessels.	Tonnage.
Outsea Boats	12	1947	18	3203
Goods and Passengers	8	600	11	834
Passengers	25	1728	26	1927
Luggage.	7	431	8	470
Towing	3	199	4	257
Total	55	4905	67	6691

In 1836 there are 75 steam vessels plying from Glasgow, some of them as long as frigates of the first class.

Intercourse with Glasgow.—The intercourse with Glasgow by coaches, steam boats, track boats, and railroads is so great that it almost exceeds belief. As several of the coaches and steam-boats depart and arrive more than once a day, and the mail coaches every day, the following may be taken as a low average of passengers by stage coaches and steam-boats, while the others are from the books of the respective companies. In 1834 Dr. Cleland published the names and destinations of 61 stage coaches which arrived and departed during 313 lawful days, each averaging 12 passengers. This gave 458, 232 in the year. By 37 steam-boats 25 passengers each, 579,050. By the swift boats on the Forth and Clyde Navigation and Union Canal, 91,975. By the light iron boats on the Paisley Canal, 307,275. By the boats on the Monkland Canal, 31,784; and by the Glasgow and Garnkirk Railroad, 118,882. These together make the gross number of persons passing and repassing to Glasgow yearly amount to 1,587,198. A number of these leave Glasgow and return to it on the same day.

Increase of Passengers.—The increase of passengers by the canal boats and railroads will be seen by the following statement:—viz. In 1836 by the swift boats on the Forth and Clyde Navigation and Union Canal, 198,461. By the Paisley Canal, 423,186. By the Monkland Canal, one boat making one trip per day, 33,400. By the Glasgow and Garnkirk Railroad, 146,296. Showing an increase in two years of 251,427 passengers. Experience has shown that the estimate of passengers by coaches and steam-boats in 1834 was taken rather too low.

Iron works in Scotland—quantity of pig iron made in the year ended on 1st May 1836.

Erected in or about years.	Name of Works.	Furnaces.	Tons.	Erected in or about years.	Name of Works.	Furnaces.	Tons.
1763	Carron Company.	5	10,400	1805	Calder . . .	5	18,200
1785	Clyde	4	14,560	1805	Shotts . . .	1	3120
1786	Wilsontown . .	1	4160	1825	Monkland . .	3	10,920
1790	Muirkirk . . .	3	7800	1828	Gartsherrie .	5	18,200
1790	Cleland . . .	1	2080	1834	Dundyvan . .		14,560
1790	Devon	2	6240				
					Total .	34	110,240

Exclusive of the above furnaces there are 22 additional ones in a state of forwardness, viz. 4 at Somerlie, 4 at Govan, 4 at Carluke, 1 at Shotts, 2 at Monkland, 4 at Coltness, 1 at Gartsherrie, and 2 at Calder. These will make 79,560 tons, and the whole 56 furnaces will make 189,800 tons of iron annually. In 1825 the quantity of pig iron made in Scotland amounted only to 55,500 tons, of which 2,862 tons was exported from Glasgow. In 1836, 23,792 tons were exported from this city.

The above works are all in the neighbourhood of Glasgow excepting five, and none of them are thirty miles distant from that city.

Post-office.—On 17th November 1709, when the magistrates of Glasgow applied to Parliament for a riding post between their city and Edinburgh, the whole Post-office revenue of Scotland was under 2,000*l.*

Revenue at the following Dates.

	£	s.	d.		£	s.	d.		£	s.	d.
July, 1781	4341	4	9	July, 1825	34,190	1	7	July, 1833	36,481	0	0½
— 1810	27,598	6	0	— 1830	34,978	9	0½	— 1834	37,483	3	4
— 1815	34,784	16	0	— 1831	35,642	19	5	— 1835	39,954	4	6
— 1820	31,533	2	3	— 1832	36,053	0	0				

Quarter ending 5th April, 1835, 10,019*l.* 11*s.* 3*d.*; 5th July, 9,904*l.* 8*s.* 4*d.*; 5th October, 9,814*l.* 18*s.* 8*d.*; 5th January, 1836, 10,215*l.* 6*s.* 3*d.*

Bridewell.—In 1835–6 there were 1613 commitments,—viz. males above 17 years of age, 738; ditto below 17 years, 213; females above 17 years, 589; ditto below, 17 years, 73. Persons committed during the year, 1946; of whom liberated, 1632; remaining on 2nd August 1836,

314. Average number daily in the prison, 270; viz. males, 157; females, 113.

Abstract accounts for the year ended 2nd August 1836,

Disbursements....................................		£2,627 17 6
Receipts for work, &c..............	£2,267 17 6	
Balance, being the cost to the public for maintaining and keeping prisoners, including all salaries, bed and body clothes, washing, furniture, working utensils, machinery, repairs on the buildings, keeping the ground in order, and everything else connected with the internal management of the establishment..	360 0 0	
		2,627 17 6

The deficiency of 360*l.* when applied to 240, the daily average number of inmates sentenced to labour, shows the expense of each prisoner to be only 1*l.* 10*s.* per annum, 2*s.* 4*d.* per month, or nearly 1*d.* per day.

In 1828 Dr. Cleland ascertained that from 1st May 1827, to 1st May 1828, there were 17,840 bullocks slaughtered in the city and suburbs, and 144,900 sheep and lambs. The value of the butcher meat in the above year (details published in the Annals of Glasgow) was 303,978*l.* 14*s.* 5*d.*; bread, 177,266*l.* 10*s.* 8*d.*; milk, 67,342*l.* 10*s.* Total value of meat, bread, and milk, 548,587*l.* 15*s.* 1*d.*

On the comparative Value of the Mineral Productions of Great Britain and the rest of Europe. By JOHN TAYLOR, *F.R.S., &c.*

A calculation, he said, was made by Mr. C. F. Smidt, in 1829, of the value of the mineral productions of Europe, at continental prices; and, from the accuracy of the statements coming within Mr. Taylor's own knowledge, he was disposed to believe in the others. It should be borne in mind that the continental prices differed greatly from those in England, and, consequently, that the amounts were comparative, and not absolute value. The value of the mineral products of Europe, including Asiatic Russia, were,—gold and silver, 1,943,000; other metals, 28,515,000; salts, 7,640,000; combustibles, 18,050,000; making in round numbers a total of about 56 millions exclusive of manganese. Now to this amount Great Britain contributed considerably more than one half—viz. 29 millions, in the following proportions:—silver, 28,500; copper, 1,369,000; lead, 769,000; iron, 11,292,000; tin, 536,000; salts, 756,250; vitriol, 33,000; alum, 33,000; coal, 13,900,000. He then gave a sketch of the history of mining in Great Britain, dwelling strongly on its vast increase since the introduction of the steam-engine.

The following is Mr. Taylor's estimate of the quantity of lead raised in Great Britain in the year 1835.

	Mines of		Tons.
Northumberland, Cumberland, and Durham.	T. W. Beaumont, Esq. ..	9,500 Fodders	10,000
	Manor of Alston, Greenwich Hospital	14,139 Bings of Ore, producing	3,850

			Tons.
	Greensides Mine in Patterdale, and other Mines in the West of Cumberland........	....	700
	Dufton, Crossfell, Hilton and Lunedale	....	1,000
	Derwent Mines	....	1,200
	Bollihope...............	231	
	Tynehead...............	140	
	Fallowfield	100	
	Sherlock and Co. and Jobling and Co.	250	721
	TEESDALE.		
	Duke of Cleveland's Liberty, and Mr. Hutchinson's of Shornbury	11,100 Bings of Ore	2775
Yorkshire	SWALEDALE,		
	Arkindale, and country adjacent	....	1000*
	Grassington, and other Manors of the Duke of Devonshire	....	700
	Pateley, Greenhough Hill, &c.	....	1000*
Derbyshire	About 8 furnaces in constant work, at 10 Tons per week	....	4000
Shropshire	Snailbeach Mine........	1300	
	Bog Mine	1554	
	Grit and Gravel Mines ..	685	3539
Devonshire and Cornwall	Wheal Betsy	40	
	And other small Mines ..	100	140
North Wales....	The Lead smelted in Flintshire in the year, was	13415 Tons	
	In Denbighshire	177	13592
Flintshire......	Of which was produced from Ores raised in Flintshire..........	....	9380
Denbighshire ..	....	....	177
South Wales.			
Cardiganshire ..	Smelted in Flintshire	1020	
	Bristol	180	1200

			Tons.
Ireland........	Smelted in Flintshire	500	
	Ireland	700*	
		——	1200*
Isle of Man	Smelted in Flintshire		850
Scotland	Scotch Mine Company ..	600	
	Wanloch Head Mines....	700	
		——	1300

The numbers on which Mr. Taylor has no certain information are marked *.

Observations on the Periodicity of Births, showing the total Number born in each Month; the Number of Premature Children; the Sex, &c. &c.; the Number of Stillborn Children, and Children Dying; also with regard to the Death of the Mothers, and the most important Complications met with in Delivery, deduced from the Experience of 16,654 *Cases. By* Robert Collins, *M.D., late Master of the Dublin Lying-in Hospital.*

This communication was supplementary to a former series of tables and deductions†, derived from the same accurate registry kept by Dr. Collins in the Lying-in Hospital, Dublin, for a period of seven years, commencing November, 1826, during which 16,654 births took place. These are classed with reference to several important points in the following table, (37 being omitted, because the sex was not noted). The following are extracts.

Months.	Total Children Born *Monthly*.	No. of *Males* in each Month.	*Premature* Births in each Month	Premature *First* Children.	Total *First* Children.	Premature *Males* in each Month.	No. of *First* Children Males.
January ..	1493	761	39	18	418	23	209
February..	1315	676	34	10	366	19	190
March....	1475	754	38	15	410	17	216
April.....	1382	738	43	12	405	17	225
May......	1375	701	44	14	417	19	203
June	1352	702	42	10	391	24	216
July......	1389	747	41	17	405	24	221
August ...	1366	718	49	14	440	28	234
September	1367	686	34	13	407	16	220
October...	1371	663	54	22	434	26	227
November.	1369	701	34	13	472	19	254
December.	1363	701	46	14	422	23	207
Totals....	16617	8548	498	172	4987	255	2622

† A short abstract is given in Vol. iv. *Reports of the Association*, under the head of "Transactions of the Sections," p. 106.

In order to ascertain the results at *different periods* of the year, with regard to most of the above calculations, I divided the years into *quarters*, as given in the succeeding table:—

Quarters.	Total Children Born *Quarterly*.	No. of *Males*.	*Premature* Births.	Premature *First* Children.	*Total* First Children Quarterly.	Premature *Males* Quarterly.	No. of *First* Children Males.
Jan., Feb., March.	4283	2191	111	43	1194	59	615
April, May, June.	4109	2141	129	36	1213	60	644
July, Aug., Sept.	4122	2151	124	44	1252	68	675
Oct., Nov., Dec.	4103	2065	134	49	1328	68	688
Totals..........	16617	8548	498	172	4987	255	2622

The total number of children *still-born* in the Dublin Lying-in Hospital during the seven years the medical charge was intrusted to me, was *one thousand one hundred* and *twenty-one*; thus eighty-four occurred in January, and so on.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
84	74	91	93	85	95	98	97	98	117	83	106

The following statement with respect to children dying in the Hospital, exhibits a similarly near approach at all seasons of the year; thus, of the total number, 284, 26 died in January, &c.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
26	19	24	25	23	20	25	20	23	30	24	25

The following table shows the periods at which the several *women* died, during my residence in the Hospital. The total number was *one hundred* and *sixty-four*; of these eighteen died in January, &c.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
18	20	10	13	17	15	6	11	15	11	16	12

In order to ascertain accurately the result as to *periodicity*, with respect to the most frequent, as well as the most important *complications* met with in delivery, I have taken the dates from my registry, and arranged them in tables in the following order.

Labours complicated with Hemorrhage of *every* variety.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
9	9	12	8	12	10	17	14	9	11	9	11

Of 131 cases of labour complicated with hemorrhage of every variety, the greatest proportionate number (17) occurred in July; the least (8) in April. Of 239 cases of labour complicated with twins, the largest proportion (33) occurred in July; the least (12) in December. Other tables of complicated labours are presented, from which, owing partly to the fewness of the cases, Dr. Collins does not venture to draw any inferences as to the periodicity of the occurrences.

Facts and Calculations on the present State of the Bobbin Net Trade, and the past and present State of the Hosiery Trade. By W. Felkin, *of Nottingham.*

From these very laborious and detailed communications, the following are extracts relating to the bobbin net trade.

Capital employed in spinning and doubling the yarn required:—in 1831, 935,000*l.*; 1833, 760,000*l.*

Capital employed in bobbin net making:—1831, 2,310,000*l.*; 1833, 1,932,000*l.*

Number of hands employed:—in 1831, 211,000; 1833, 159,300.

Value of raw material and manufactured goods:—

1831.	Amount of South Sea cotton, 1,600,000 lbs., value, 120,000*l.* .... Amount of raw silk, 25,000 lbs., value, 30,000*l.*..	150,000*l.*
,,	The same when made into a state fit for the bobbin net makers	540,000*l.*

1831.	Value of 23,400,000 square yards, annual produce of bobbin net	1,891,875*l.*
1833.	Amount of South Sea cotton, 2,387,000 lbs., raw	224,000*l.*
,,	The same in yarn fit for the bobbin net makers	766,000*l.**
,,	Value of 30,771,000 square yards of English bobbin net	1,850,650*l.*
1835.	Amount of South Sea cotton, 1,850,000 lbs., worth	185,000*l.*
,,	Amount of raw silk	25,000*l.*
,,	The same when fit to be used in the bobbin trade	664,330*l.*
,,	Value of the bobbin net	2,212,000*l.*

Mr. FELKIN also communicated some observations on the difficulties which impede the collecting of accurate statistical information.

On the Utility of Co-operating Committees of Trade and Agriculture in the Commercial and Manufacturing Towns of Great Britain, &c. as projected by Mr. Holt Mackenzie and Mr. Forbes Royle, and advocated by Sir Alexander Johnston and Sir C. Forbes, for investigating more exclusively the Natural and Artificial Products of India. By Colonel SYKES.

The object of the paper was to invite the formation of committees, as suggested in the above title, in our principal manufacturing and commercial towns, either in co-operation with the Royal Asiatic Society, or independently, for the following purposes:—

1. To ascertain what articles, the produce of India, now imported into England, are of inferior quality to those produced in other countries; to investigate the causes of the inferiority, and to explain and suggest means for removing them.

2. To ascertain what articles now in demand in England, or likely to be used if furnished, but not yet generally forming part of our commerce with India, could be profitably provided in that country, or their place advantageously supplied by other things belonging to it; to take measures for making known in India the wants of England, and in England the capabilities of India; and to suggest and facilitate such experiments as may be necessary to determine the practicability of rendering the resources of the one country subservient to the exigencies of the other.

3. To ascertain what useful articles are produced in countries possessing climates resembling those of the different parts of India which are not known to that country, and *vice versâ*. To consider the means of transplanting the productions, and transferring the processes of one country to another; and to encourage and facilitate all useful interchanges of that nature.

4. With the above views, and for the sake of general knowledge and improvement, to consider how the statistics of Indian agriculture and arts (including climate, meteorology, geology, botany, and zoology) may

* Above 100,000*l.* worth of this yarn was sent abroad (262,000 lbs.).

be most conveniently and œconomically ascertained and recorded; and to encourage and facilitate all inquiries directed to those objects.

Numerous illustrations of these national considerations were quoted from Mr. Royle. It appeared that so lately as 1784, an American vessel arrived at Liverpool with eight bags of cotton, which were seized, under the belief that America *did not produce* that article; and now her produce is four hundred millions of pounds, the greater part of which is consumed in Great Britain; and it is remarkable, that the native country of the Sea Island cotton is supposed to be Persia. The Carolina rice, which sells at 5*d*. per lb., whilst the best India rice sells at only 2½*d*. or 3*d*., originated in a single bag of East India rice given by Mr. C. Dubois, of the India House, to an American trader. All the coffee of the West Indies originated in a single plant in the hot-houses of Amsterdam.

Of new or little-known articles lately introduced from India, and which are of the utmost importance to our manufacturing interests, it was stated that in 1792, Mr. Brown, the resident at Cossimbazar, told the council at Calcutta, that if it should think proper to send a few cwts. of lac to Europe, it *might* be procured in Calcutta. The annual consumption in England is now estimated at six hundred thousand lbs. Catechu was so much neglected that its price was as low as 2*s*. per cwt.; it was discovered to be useful in dying cotton a peculiar brown, and is also employed in tanning; and its price is steady at 40*s*. per cwt. Royal safflower is another article of curious illustration. Ten years since only Turkey safflower was known, and now East India alone commands the market. Rape-seed, recently introduced, has, it is understood, produced a profit to one mercantile house of £40,000. Flax or linseed, for which we are dependent on Russia for 50,000 tons annually, was first imported from India in 1832: it was found to be better than the Russian, and the crushers gave 15*s*. per cwt. more for it. The importation has amazingly increased, and England will doubtless ere long look to her own dependencies for the total supply of her wants. In India even, some kinds of Indian iron have recently been sold at more than double the price of the English iron. The rapid increase of the importation of castor and cocoa-nut oils was mentioned; and specimens of cocoa-nut fibre, as a valuable, cheap, and healthy substitute for horse-hair, in stuffing mattresses, &c., were exhibited. Many other articles were enumerated as of great value to the manufacturers of England; gums, resins, varnishes, oil and cordage, plants, &c., &c., besides articles of the Materia Medica, such as senna, rhubarb, &c., &c., &c.

On Spade Husbandry in Norfolk. By Dr. Yelloly.

On the Effect of Railroads on Intercommunication. By Dr. Lardner.

The subjects discussed by Dr. Lardner, were the relative numbers of persons travelling now by railroads, and formerly by coaches, between the same points; the general proportion being as 4 to 1, a result due

to the diminished price and augmented speed. The comparative effect of swift packets on canals was stated to be very small. The practicability of augmenting the celerity on railroads to even fifty miles an hour was advocated, and illustrated by the results of actual trials.

Outlines of a Memoir on Statistical Desiderata. By W. R. Greg, *Esq.*

In this communication the author brought forward proofs of the total deficiency of statistical information on some subjects of national importance, and the unsatisfactory nature of that which had been collected by public authority, on others. From examinations of population tables, tables of births and deaths, criminal statistics, the statistics of education, of illegitimate birth, and of stolen property, the author is led to conclude, that "with the exception of the revenue and commercial tables, no general statistical documents yet exist in England from which any philosophical inferences can be safely drawn, and that till the materials are wholly re-collected, all attempts to elicit such inferences can only end in disappointment and error." In order to obtain more satisfactory results in future, he deems it highly necessary to depart from the plan so commonly resorted to, of issuing *circular queries,* and to commit the task of obtaining authentic and complete information to individuals who shall make the execution of it their professional duty, and whose labours shall be remunerated accordingly.

On Formula of Returns of the gross Receipts of the Revenues of Great Britain, and of Savings Banks Returns. By Jeffries Kingsley, *Esq.*

The object of this communication was to enforce the propriety and advantage of an uniform and well-considered plan of gross, rather than net returns, on the above-named subjects, under the authority of Parliament.

M. Le Play presented to the Section a copy of a "Resumé des Travaux Statistiques de l'Administration des Mines en 1835."

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END OF THE FIFTH VOLUME.

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